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Grasshoppers

GRASSHOPPERS OF BRITISH COLUMBIA.

By R.C.Treherne and E.R.Buckell.

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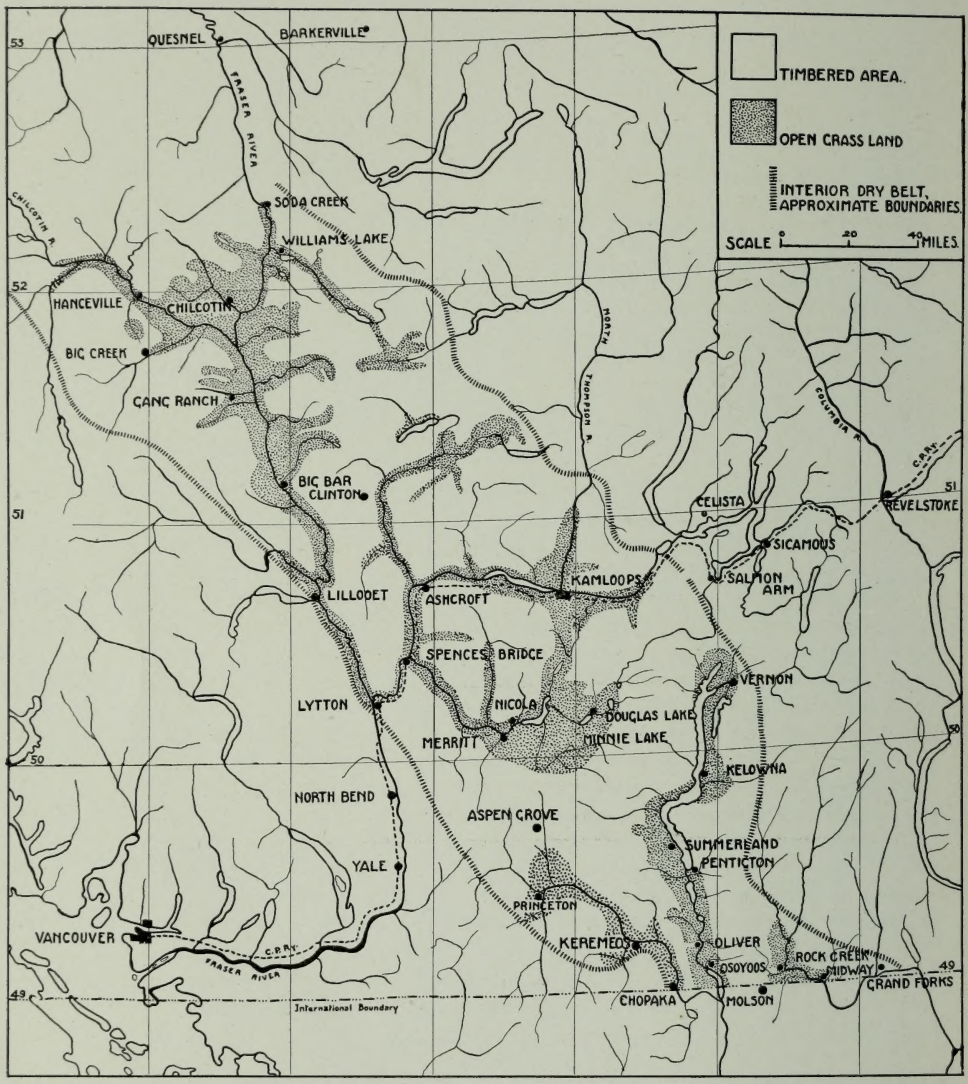

Fig. 1—Map of southwestern British Columbia showing the approximate boundaries of the interior dry belt and the areas of open grassland (after Whitford and Craig, Commission of Conservation of Canada Report 1918) dealt with in this publication.

The Grasshoppers of British Columbia[1]

With particular reference to the influence of injurious species on the range lands of the province.

By R. C. Treherne[2] and E. R. Buckell

INTRODUCTION

In the dry interior region or "dry belt" of British Columbia, situated between the 49th and 53rd parallels, many indigenous species of grasshoppers may be found. At least fifty different species have thus far been taken within this area and there is little doubt that many more species and varieties will be discovered by further diligent search.

Similar to many other forms of insect life, grasshoppers are subject to years of abundance. Often large areas are affected by certain species and during outbreaks the native vegetation as well as cultivated crops is severely injured. The species which have been noted in the past as particularly injurious are those that are able to increase and multiply under open-plain conditions. The agricultural development of the interior regions of British Columbia has occurred in the last fifty years, during which time large areas, previously untouched by man, have been broken for the cultivation of crops or utilized as ranges for stock. It is in those portions of the province which are unfavourable for the production of tender fruits and vegetables and which have been utilized as stock ranges, that grasshopper injury has been most pronounced. It is well to emphasize this point for the reason that the degree of prevalence of grasshoppers on the range, influences the prevalence of these insects on adjacent cultivated land. In the southern sections of the province, particularly suited to the production of fruits and vegetables, considerable damage has on occasion been caused by grasshoppers to plantings of young fruit trees, intercrops and vegetables. When such occurred the unbroken bench lands immediately surrounding these plantings were the breeding grounds of the grasshoppers.

Dry farms adjoining range areas frequently suffer great loss by these insects which breed in large numbers on the open plains and which attack the hay and grain crops being raised. The same applies to ranch meadows where, usually under irrigation, crops of hay and grain are being grown for winter cattle feed.

Furthermore, grasshoppers have been known at times to appear in tremendous numbers and to have caused a great deal of inconvenience to farmers and settlers in the semi-humid and humid sections of the province.

There are approximately five thousand square miles in British Columbia, especially adapted, at the present time, to the raising of cattle, sheep and horses. Over these areas, which include the Similkameen, Nicola, Kamloops, Ashcroft and Chilcotin districts, grasshoppers have occurred, in the form of outbreaks, at regular intervals every six or seven years. As the country became more settled and as the range became more systematically grazed, grasshoppers found a considerably widened area suited to their development so that in many sections today, where the range is avowedly over-grazed, immense breeding areas have been produced. Consequently, the species which find partially depleted conditions suited to their liking have become the commonest and most injurious kinds.

The outbreak of 1921-23 was the worst in the history of the province. It would not be strictly accurate to connect too closely the condition of overgrazing with grasshopper prevalence. Unquestionably the two are intimately related but the severe outbreak of 1922 was undoubtedly influenced by con-

[1]Much of the information presented in this bulletin was obtained by Mr. Buckell while in the employ of the Provincial Department of Agriculture.

[2]*Obit.* June 7, 1924.

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ditions climatic or otherwise favourable to grasshopper increase. The outbreaks of the past have varied in their relative importance and the outbreaks of the future will do likewise. There are many factors bearing on this question which it is the purpose of this bulletin to discuss. Five years have been spent in a study of the influence of grasshoppers on the cattle ranges of British Columbia. In 1919, the study was undertaken in the Lower Okanagan and Rock Creek sections, in 1920 and 1921 in the Chilcotins and in 1922 and 1923 in the Nicola valley from Kamloops to Princeton.

DESCRIPTION OF A TYPICAL RANGE AREA

It is important that a description of a typical range area be given in order to appreciate the significance of what are termed "summer" and "winter" range areas. In short, the range areas generally utilized during winter for stock feeding are the main U-shaped river valleys which are commonly terraced (fig. 2), while the summer ranges consist of the uplands and the valleys of the small tributary streams which extend back from the main valleys into the uplands.

Fig. 2—Typical winter range on the Fraser river at the mouth of Riske Creek, Chilcotin, B.C., with summer range in distance. (Original)

The Riske Creek Range (Chilcotin)

The Riske Creek range is a triangular piece of country lying in the angle made by the junction of the Chilcotin and Fraser rivers (see map, page 2). This area contains about three hundred square miles, by far the greater part of which is open grass land. It forms part of an undulating plateau which varies in elevation from 3,000 to 3,500 feet. The rivers bounding this area on two sides lie in deep-terraced, U-shaped valleys, from 1,500 to 2,000 feet below the level of the main plateau (fig. 2). This district at Big Creek has a mean annual temperature of 37 degrees Fahr., with an annual rainfall of about 15 inches.

The open portions of this range were originally covered with a fine stand of bunch grass, *Agropyrum tenerum* Vasey, which grew often from two to three feet in height. The settlers at the time were in the habit of mowing this grass and stacking it for hay. Today it has been practically destroyed, due largely to overgrazing, assisted by the influence of grasshoppers. Several plants which are typical of the "dry belt" are found, among which may be mentioned the

rabbit-brush, *Chrysothamnus graveolens* Nutt., and the cacti, *Opuntia polyacantha* Haw., and *O. fragilis* Haw.

The main plateau of the Riske Creek range lying south of a line drawn from Hanceville on the Chilcotin river to Soda Creek on the Fraser river is almost entirely open grass land (fig. 3), on which innumerable clumps and patches of timber grow. The common pasture wormwood, *Artemisia frigida* Willd., also grows profusely, mingling with the grass and forming, especially after frost in late autumn, a valuable food plant for cattle. The timber is either aspen, *Populus tremuloides* Michx., or douglas fir and lodgepole pine. In many cases the centre of the clump is composed of fir and pine, while a narrow belt of aspen fringes the outside. These patches of timber may be less than an acre in extent or may cover an area of from 200 to 300 acres. In moist locations, such as the margins of lakes and in creek bottoms, the western birch, *Betula occidentalis* Hook, is often associated with the aspen, and several species of willow, *Salix* spp., are commonly found.

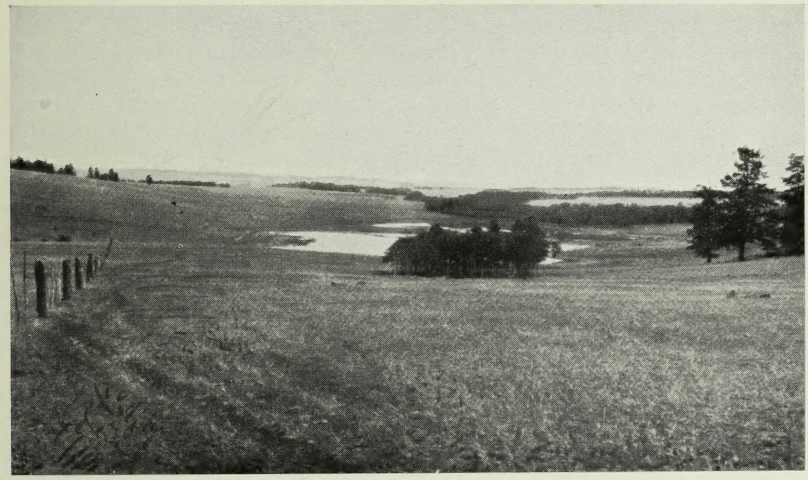


Fig. 3. View of the Riske Creek range showing typical clumps of timber and small lakes. (After Hadwen)

On the warmer slopes the rocky mountain junipers, *Juniperus scopulorum* Sarg., and *J. communis* L., are common. The range is well watered by several creeks and innumerable lakes, many of which are permanent.

This area, with the vast timbered country to the north, forms the summer range for the cattle. There is, however, a very large area of land on the steep slopes of the river valleys which is to some extent thickly timbered. These areas are, also, used for summer ranges but there are many open sections on these river slopes which, in the main, form the winter ranges for the cattle. The river valleys thus serve a dual purpose, depending on local conditions and requirements.

The upper range often ends very abruptly and descends precipitously in a series of terraces to the rivers, which are from 1,500 to 2,000 feet below. These steep river valley slopes are of two distinct types; those facing towards the north and east being heavily timbered and of little value to the cattle industry, except as optional summer ranges; and those facing towards the south and west being free from timber, covered with bunchgrass and consequently very valuable. Scattered douglas firs may be found on these southern slopes, and the ravines, often cut deep by former water courses, contain sage-brush and rabbit-brush in some quantity. Near water and in moist places, *Amelanchier cusickii*

Fer., and *Symphoricarpus racemosa* Michx., are found growing. Bunch-grass and allied species of grass form the main type of vegetation so that these slopes are the main winter ranges for cattle. The majority of these slopes are and have been for many years fenced in and all cattle and horses kept off them except during the winter. They still produce a fair stand of bunch-grass in strong contrast to the unfenced areas of these river slopes which are similar in condition to the upper ranges in point of depletion and which are clothed with such plants as are given in list No. 2 on page 12.

The Kamloops-Nicola Range Area

The Kamloops-Nicola range is a very large tract of land which in general features closely resembles the Riske Creek range. It lies mainly to the south of the Canadian Pacific railway at Kamloops and extends to the Kettle Valley railway at Princeton, a distance of about 120 miles. Considering only the open grass land and the more lightly timbered areas we find a varying width of from 15 to 35 miles, enclosing an area of about 3,000 square miles of typical cattle range. Adjoining this area there is a smaller range immediately north of Kamloops lying on either side of the North Thompson river and another, which we may call the Princeton-Keremeos range, lying to the south of the Kettle Valley railway and extending on either side of the Similkameen river to the international boundary. This latter is of considerable size though not as large as the Kamloops-Nicola range. If we add to these ranges the more heavily timbered regions flanking them on either side, and into which many of the cattle penetrate for long distances during the summer months, the areas must be doubled. Although this range lies 200 miles further south than the Riske Creek range there is very little difference in the flora and fauna. The general level of the summits of the higher land in the Kamloops-Nicola region varies from 4,000 to 6,000 feet. It is far more broken up and hilly than the Riske Creek range. It is furthermore well watered by several rivers and streams and contains many lakes, some of which are of considerable size. The area is largely fenced and it is only in the timbered summer ranges that any very extensive unfenced areas can be found. The western yellow pine, *Pinus ponderosa* Dougl., is the dominating tree, except on the highest levels where the douglas fir and lodgepole pine mingle with it. This pine is entirely absent from the Riske Creek range.

HISTORY OF GRASSHOPPER OUTBREAKS

Over these areas, just described, grasshoppers have occurred since the earliest recorded times.* No year has passed when grasshoppers were entirely absent. However, as is usual, years of prevalence occur while the intervening years are not marked by any unusual circumstances. Various natural forces are continually at play which alter or vary the existing numbers of insects. Without expanding the actual records dealing with the years when grasshoppers were in outbreak form, the graph (fig. 4) has been prepared to demonstrate the approximate high points in prevalence in the Okanagan and Nicola valleys. This graph has been arrived at in a purely hypothetical manner as no comparative data were obtainable. It is, thus, quite imperfect but represents in the best manner possible the apparent relative importance of the various outbreaks as they occurred.

Other Localities.—In the Kootenay sections, grasshoppers have occurred commonly and at times have caused comment from the injuries they produced. No outstanding outbreaks, however, to our knowledge, have taken place. To the Lower Fraser valley the same statement may be applied, with the exception

*According to A. Handlirsch (Contr. Can. Pal. Vol. 2, Pt. 3, 1910). Orthopteroid material is found in tertiary lake deposits at Horsefly Mine, near Quesnel, B.C.

that in 1919 the red-legged grasshopper, *Melanoplus femur-rubrum* (De Geer), occurred in great numbers on the Matsqui prairie. Garden produce was attacked on this occasion and oats were cut for hay owing to the damage being caused.

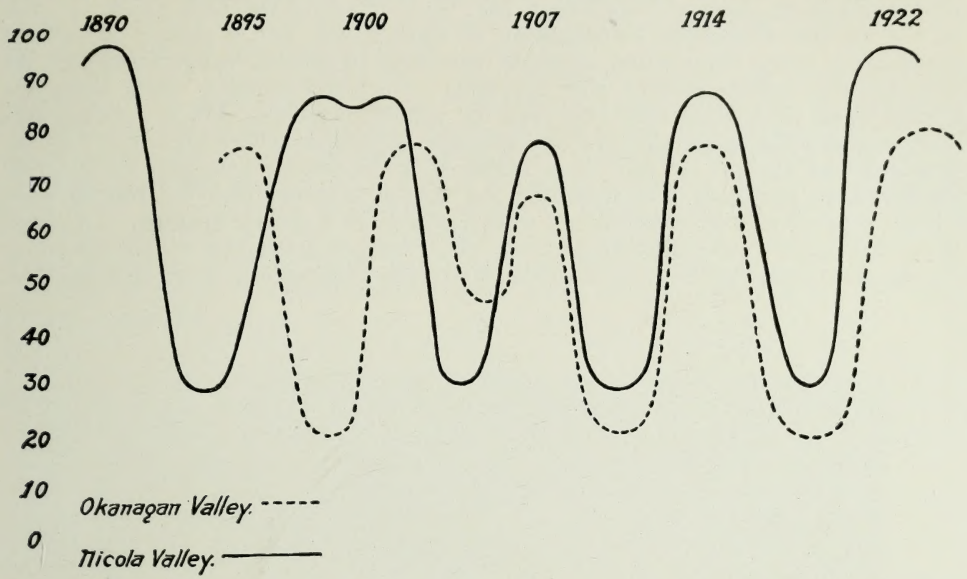


Fig. 4—Graph showing hypothetically the heights of the grasshopper outbreaks in the Okanagan and Nicola valleys respectively during the years indicated.

This was the first time in the history of the district in which grasshoppers had become numerous enough to cause material harm and their numbers on this occasion, doubtless, were influenced by the somewhat dry climatic conditions preceding the outbreak.

Occasional occurrences of great numbers have been noted at points in the semi-humid sections of the province. The most notable of these was a severe outbreak of the lesser migratory grasshopper, *Melanoplus mexicanus atlanis* (Riley), at Celista, 14 miles north of Notch Hill, where 150 acres of crop were involved.

Lastly must be mentioned the damage liable to occur at times to the crops being grown on the dry farms adjoining range territory. Reports of such losses have been received from many different and widely separated points in the Province of British Columbia. The years when the greatest amount of damage is suffered, as would be expected, coincides with the years of grasshopper abundance on the open range.

CAUSES OF RANGE DEPLETION

There must be a reason for the outbreaks of grasshoppers that have occurred in the interior sections of British Columbia, during the past forty years. It is possible that in the years previous to 1889, periods of extreme prevalence took place of which we have no record. Even granting that these periods did occur, no permanent or material damage to the range grasses took place until twenty to thirty years ago, as is evidenced by the excellent stands of bunch grass over the entire "dry belt," recollection of which is still present in the minds of those who have been resident in the districts for a long time (fig. 5). It is not necessary however, to rely on hearsay to realize that where the numbers of stock to the area available for ranging is in judicious proportion or where rotations of grazing grounds are practised, grasshoppers do not, or even cannot, permanently injure the range grasses.

Movements of cattle into British Columbia began in the "sixties" at the time of the gold discoveries on the Fraser river when herds were driven up from Oregon, Washington and California to provide food for the great influx of miners that was taking place at that time. Mr. G. C. Hay, of the Live Stock Branch of the British Columbia Department of Agriculture, has a record of several small herds being established at about this time in interior range sections. At that time no winter feeding was necessary, the lower benches being kept ungrazed so as to provide sufficient feed for winter purposes. During spring and early summer the cattle were driven to higher elevations where luxuriant vegetation awaited them. As Mr. Hay states in a report he prepared on interior stock-raising problems, "in this way the winter, summer and fall ranges were widely separated and broad areas were covered in a year's grazing. In those days cattlemen could pick and choose their ranges according to the season." On the completion of the Canadian Pacific Railway transcontinental line, in 1886,

Fig. 5—View of Stump lake, Nicola valley, B.C. Photograph taken by Dr. G. M. Dawson, September 6, 1890. Note excellent stand of grass. (Reproduced by courtesy of the Geological Survey of Canada, Department of Mines)

agricultural development commenced. Land formerly devoted entirely to cattle and sheep raising was converted into small holdings, where hay, grain and potatoes were grown. The increase in population, particularly in the coastal sections which were now linked up by rail with the interior, provided a considerably enlarged market. Thus the question of the convenience in handling the stock "on the hoof" close to rail connections became one of moment. The partial settlement of the land and the proximity to market facilities confined the herds, which had developed to considerable size, to more restricted areas. It would appear that the Kamloops-Nicola section was particularly favoured as a grazing area. Hence, it is not surprising, possibly, to find that the first serious outbreak of grasshoppers in the province occurred in the Nicola valley in 1889. It is not fair to state that this outbreak resulted from confined grazing limits. It was a contributing factor, doubtless, but climatic conditions favourable to grasshopper increase must have existed. The providing of summer

and winter feeding areas has always been and will remain the paramount question in the minds of cattle owners. The difficulty of providing winter feed has to some extent been overcome by the growing of timothy hay, alfalfa and grain, under irrigation, in the lower-lying meadows. This is only possible, however, within certain limits dependent upon the amount of land and water available and the labour conditions.

The Riske Creek range area in the Chilcotin districts represents a typical condition of recent development. Twenty years ago very few cattle existed upon it and the grass, which was mainly bunch grass, covered the whole of the open range and grew from eighteen inches to two feet in height (see fig. 5). Fifteen years ago several cattle outfits became established on this range possessing in all approximately 6,000 head of stock. From that time until the present the main spring and autumn ranges have never been fenced and no attempt has been made to preserve them from deterioration. With the increase in the numbers of cattle, finding the open range unfenced and undisturbed, the range stock, including horses, remained upon it almost throughout the entire year.

Fig. 6—A Typical bunch grass winter pasture in early summer showing a good stand of *Agropyrum tenerum* Vasey. (Original)

Under these conditions it was not long before the original stand of bunch grass showed signs of depletion. Stock are particularly fond of this native grass, and, given uncontrolled opportunity, soon exterminate it. Bunch grasses, *Agropyrum* spp., reproduce entirely from seed and ripen only a few seeds each year. It may be, therefore, readily destroyed if grazed too closely, too continuously, or at wrong periods of the year.

An examination of the Riske Creek range in 1920 and 1921 showed that the only bunch grass that existed in any quantity was to be found on the winter ranges which had been fenced and from which all stock had been kept from early spring until late autumn (fig. 6). The grass, had thus been given an opportunity to grow and seed itself. On the open range no true bunch grass plants could be found except in those places where cattle could not eat them, as in clumps of rose bushes, around cacti or under projecting rocks.

The bunch grasses are dominant types of plants crowding out other kinds, as may be seen in figure 6. If they are destroyed, however, a secondary class of vegetation replaces them (see list on page 12). This secondary vegetation consists of a mixed variety of grasses and plants, smaller in stature, but, as it happens, only slightly inferior in feeding value to the original bunch grass.

In fact, a range clothed in secondary grasses produces a more general-purpose grazing area, adapted to cattle, horses and sheep, than one where bunch grass predominates. The main Riske Creek range area is now in the condition where the primary bunch grasses have gone and the secondary grass stage exists (fig. 7). It is to be regretted that in many sections even these secondary grasses are being destroyed for want of an opportunity to grow unchecked for a year or two. This is particularly unfortunate as the third stage of a range is the weed stage which is of little use except to sheep.

These observations indicate clearly that the stock themselves are primarily responsible for the disappearance of the range grasses. Drought and the influence of grasshoppers are secondary factors.

The destruction of the normal vegetation opens up the range to the free action of sun and wind. A year of drought or the failure of a normal precipitation will unfavourably affect the range grasses. This deterioration affected primarily by grazing, intensified by drought, produces gradually a different environment (fig. 14). At this point it is well to appreciate that insects react

Fig. 7—View of an overgrazed range in the Chilcotin district, B.C. The bunch grass has been practically exterminated and secondary grasses and plants have taken its place. (Original)

very quickly to a changed environment, and that a normal range area embraces a wide variety of ecological conditions.

In the description already given of a typical range it will have been noticed that a variation existed from dense timber to open grassy plains. These plains, high in altitude, nearly level, often covered with scattered boulders, were originally clothed with waving grasses and herbaceous plants (see fig. 5). Here and there outcroppings of gravel occurred and rocky knolls appeared where the grass, if it were not of entirely different nature, grew shorter and less luxuriantly. Light timber, heavy timber, willow bottoms, and alkali patches were all encountered and each one represented a different habitat where not only different plants grew but different species of insects abounded. In this condition lies the explanation for the existence of the many kinds of grasshoppers mentioned previously in the introduction. In a broad general sense two main groups of grasshoppers may be found; namely (1) those inhabiting the open range where the light vegetation and the warmth of the sun provides conditions suitable to their development, and (2) those frequenting timbered areas. In a broad general sense, again, these two groups may be further divided: (1) those of the open range may frequent either the partially shaded environment of the grass land or they may live entirely on the gravel ridges and rocky knolls for part or all

of their existence; (2) those of the timbered areas may be separated into groups living in dense timber, in open glades or in marshy, wet, dark situations. In the years when grasshoppers are present in great numbers these divisions are not in evidence. Rather do we find a complex overlapping of species driven by circumstance from their normal habitat. However, in so dividing these groups of grasshoppers the explanation is found for the prevalence of certain species.

The species inhabiting light timber, for instance, should they become numerous owing to the failure of their own natural controlling factors, would be inclined to migrate further into timber rather than venture into the open plain where excessive heat, bright sunshine and open conditions are unfavourable to their development.

Furthermore, those species normally inhabiting the original bunch grass plains would not be inclined to destroy the grasses so as to render their environment distasteful. Quite apart from any assumption in this connection it has been observed that the stand of grass is not greatly interfered with by grasshoppers living in such an environment. Their eggs hatch in early summer after the grass has become well grown and the thin wiry stems and seed stalks are not touched in the feeding operations of nymphs or adults.

On the other hand, should the species which normally frequent gravel ridges or poor soil, where the vegetation is sparse and scanty, become numerous, they would migrate into the grassy range, taking advantage in their feeding operations of all the weak, low-growing and sickly plants they encountered. Herein, doubtless, lies the relationship between an overgrazed range and grasshopper abundance. It is now known that the most injurious species are those that prefer an open, bare, parched, low-grassed range condition (see figs. 7 and 14).

RANGE VEGETATION

The authors are indebted to the office of the British Columbia Grazing Commissioner, Department of Lands, Victoria, B.C., for the following lists of plants which occur on the important range sections of the province and which have been found to be of major importance to the cattle industry.

Four main divisions or botanical units may be recognized. The first division embraces the well-kept winter ranges where very little overgrazing has occurred, and where the vegetation is nearly the same as that which existed in the earlier years before the introduction of stock. Inaccessible sections of open range to which no stock have yet found access is also incorporated in this first division. These types of range are spoken of as "bunch grass ranges" and they vary from almost pure stands of bunch-grass, *Agropyrum tenerum* Vasey, figs. 5 and 6, to mixed stands of grasses and plants of types which are mentioned in list No. 1.

The second division contains what are usually referred to as the main open grass ranges, comprising all the open country except the protected sections. This division relates to the same type of range as the first division but to an overgrazed condition (fig. 7). Its outstanding characteristic is the partial extermination of the original plants, particularly bunch-grass, by grazing and their replacement by other plants which have become dominant. According to notes obtained through the office of the British Columbia Grazing Commissioner, in certain sections these secondary plants form almost pure stands. "For instance, the needle grass, *Stipa comata* T. & R., forms a pure stand over the overgrazed slopes in the vicinity of Kamloops, as *Bromus tectorum* L. and *Poa Sandbergii* Vasey do on the Lundbom commonage in the Nicola valley. *Antennaria dimorpha* T. & G. is observed forming pure stands at certain selected places, and *Erigeron flagellaris* Gray is very common on the overgrazed areas around the 105 Mile House on the Cariboo road."* The chief plants noted for this second division are given in list No. 2.

*In litt.

To the third division belongs the "timber range" which includes all the timbered portions of the cattle ranges from the lightly timbered areas on the lowlands to the thickly wooded mountain slopes. The commonest plants in this division are noted in list No. 3.

The fourth division comprises what may be termed the "mountain ranges." This class of range is very little used in British Columbia at the present time but there are immense areas available which may be used ultimately for grazing sheep. This range lies mainly above the timber line and is composed chiefly of sedges and highly nutritious mountain plants common to the Hudsonian zone. As this type of range does not greatly concern us in this publication no list of its dominant plants is given.

The following are the lists of plants for each of the three divisions mentioned, arranged in their order of abundance and importance and published by the courtesy of the British Columbia Grazing Commissioner:—

(1) List of Herbaceous Plants Found on Protected Open Range, Commonly Known as "Bunch Grass Range," in Order of Importance Determined by Palatability and Abundance.

Agropyrum tenerum Vasey	Bunch grass; slender wheat grass.
Geranium viscosissimum F. & M	Pink geranium.
Pentstemon procerus Dougl	Blue beard tongue.
Balsamorhiza sagittata (Pursh) Nutt	Sunflower or balsam root.
Lithospermum pilosum Nutt	Puccoon.
Arenaria capillaris Poir	Hair-leaved sandwort.
Achillea lanulosa Nutt	White yarrow.
Elymus glaucus Buckl	Smooth wild rye.
Koeleria gracilis Pers. (K. cristata (L.) Pers. in Henry's Flora)	Crested hair-grass.
Hordeum nodosum L	Meadow barley.
Distichlis spicata (L.) Greene	Alkali or Salt grass—near water and alkali.
Spartina gracilis Trin	Slouth grass—near water and alkali.
Muhlenbergia Richardsonis (Trin.) Rydb. (*Sporobolus Richardsonii* (Trin.) Mer. in Henry's Flora)	Near water and alkali.

(2) List of Herbaceous Plants Found on an Overgrazed Open Range, in Order of Quantity.

Stipa comata Trin. & Rupr	Needle grass.
Bromus tectorum L	Downy brome-grass.
Poa Sandbergii Vasey.	
Erigeron compositus Pursh	Small white erigeron.
Stipa columbiana Macoun.	
Hordeum jubatum L	Squirrel-tail grass.
Sitanion velutinum Piper	White foxtail.
Bromus hordeaceus L	Soft chess.
Taraxacum officinale Weber	Common dandelion.
Eriogonum heracleoides Nutt.	
Antennaria dimorpha T. & G	Everlasting (pure stand in spots).
Erigeron lonchophyllus Hook	Yellow erigeron.
Erigeron flagellaris Gray.	
Salsola kali L	Russian thistle.
Trisetum spicatum (L.) Richter	False oat.
Agropyrum tenerum Vasey	Bunch grass.
Artemisia frigida Willd	Pasture wormwood.
Hordeum nodosum L	Meadow barley.
Sisymbrium canescens Nutt *Sisymbrium incisum* Engelm	Mustards
Plantago Purshii R. & S	Woolly plantain
Chenopodium album L	Lamb's quarters
Sporobolus asperifolius (Nees & Meyen) Thurb	Pepper grass
Antennaria aprica Greene	Everlasting
Thlaspi arvense L	Penny cress
Atriplex argentea Nutt	
Lappula floribunda (Lehm) Greene	False forget-me-not

All about equal in stand.

The nomenclature is in accordance with that of Henry's Flora of Southern British Columbia, Toronto, 1915, except in a few cases when, however, Henry's names are given in parenthesis. We are indebted to Dr. M. O. Malte, Chief Botanist of the National Herbarium of Canada for checking over the above lists.

(3) List of Herbaceous Plants Found on a Timber Range in Order of Abundance.

Calamagrostis suksdorfii Scribn.	Pine grass.	
Lupinus lepidus Dougl.		
Lupinus argenteus Pursh.		
Aster radulinus Gray.		
Astragalus campestris Gray	Milk vetch.	
Astragalus tenellus Pursh	Milk vetch.	
Melica bella Piper (*M. bulbosa* Geyer in Henry's Flora)	In parts of British Columbia.	
Delphinium Menziesii DC.	Low larkspur.	
Erigeron speciosus DC.		
Luzula campestris (L.) DC.	Wood rush.	
Luzula parviflora (Ehrh.) Desv.	Wood rush.	
Carex atrata L.	In parts of British Columbia.	
Lomatium utriculatum (Nutt.) C. & R.		
Lomatium nudicaule (Pursh.) C. & R.		
Vicia americana Muhl.	Pea vine.	
Vicia angustifolia (L.) Reich.	Common vetch.	
Geranium viscosissimum F. & M.	Pink geranium.	
Solidago lepida DC.	Golden-rod.	
Koeleria gracilis Pers. (*K. cristata* (L.) Pers. in Henry's Flora)	Crested hair-grass.	
Bromus eximius (Shear) Piper		About evenly distributed.
Senecio pseudaureus Rydb.		
Pedicularis racemosa Dougl.		
Polygonum Douglasii Greene.		
Phacelia linearis (Pursh.) Holz. (*P. Menziesii* Torr. in Henry's Flora)		
Phacelia leucophylla Torr.		
Mertensia paniculata (Ait.) Don.	Lungwort (some parts of British Columbia)	
Castilleja, various species	Indian paint-brush.	
Anaphalis margaritacea (L.) B. & H.	Pearly everlasting.	
Epilobium angustifolium L.	Fire-weed or willow herb	
Cerastium arvense L.	Field mouse-ear chickweed	

SPECIES OF GRASSHOPPERS OF ECONOMIC IMPORTANCE

Grasshoppers belong to the insect order Orthoptera in which is also included such insects as cockroaches and crickets. The name "grasshopper" is usually applied to the members of the family Acridiidae which contains an immense number of species. They may be recognized by the fact that their antennae or "feelers" are short, usually less than half the length of the body and composed of from 6 to 24 segments or joints. The wings and wing-covers (tegmina) rest partly deflexed against the sides of the abdomen. The fore and middle legs are nearly of equal size but the hind legs are much longer with the thighs (femora) greatly enlarged and fitted for leaping. The ovipositor, consisting of four, short, stout pieces, two of which curve upwards and two downwards, projects from the tip of the abdomen.

Grasshoppers lay from ten to one hundred eggs, varying with the different species. The eggs are large in comparison with the size of the insect and are usually laid beneath the surface of the soil (fig. 8). The female, in the act of egg-laying, chooses a suitable spot and gradually bores down into the soil by alternately opening and closing the horny projections which comprise her ovipositor. When the required depth has been reached the eggs are laid, side by side, in regular order, surrounded by a frothy matrix which binds them together and causes the particles of earth to set in the form of a cement wall around the egg pod. The top of the egg pod, unless laid in a clump of grass, reaches to within half an inch of the surface of the ground and the cavity above is filled with dry soil after the withdrawal of the abdomen. In the majority of cases the injurious species deposit eggs in the late summer and the winter is passed in the egg stage below the ground.

In the spring, as soon as the soil has become sufficiently warm, the young grasshoppers break through the shell of their eggs, force their way upwards through the loosely filled soil chamber above the egg pod and appear upon the surface of the soil. Lying on their sides and struggling vigorously in the warm air they soon succeed in tearing through their first nymphal membrane and crawl away a short distance from the egg pod to rest and harden in the sun. These young grasshoppers, nymphs, or "hoppers" as they are called, closely

Fig. 8. Grasshopper laying eggs. (After Gibson)

resemble the adult in appearance except for their small size and total absence of wings (fig. 10). They commence to feed almost at once and undergo a series of moults as they increase in size. At each moult the nymph more closely resembles the adult and wing pads appear upon the back. With the last moult the mature insect emerges with fully developed wings. In this stage it is referred to as the "adult." These adults spend the summer feeding, basking in the sunshine and migrating until they are ready to deposit eggs. After mating and ovipositing they linger on for a few weeks until killed by the frosts of early autumn.

In addition to the species of the family Acridiidae, there are several species of economic importance belonging to the Tettigoniidae or long-horned grasshoppers. The mormon, coulee and cave crickets and the katydid belong to the Tettigoniidae. They are erroneously called crickets and must not be confused with the true crickets or Gryllidae to which the tree crickets, field crickets and mole crickets belong, none of which are of any economic importance upon the range lands of British Columbia.

The Tettigoniidae (Plate 3) have very long and slender antennae which often exceed the length of the body. The females of the chief economic species, to which reference will be made, are wingless, while the males are provided with short rounded wings bearing musical organs on their basal portions. The ovipositor is long and sword-shaped and the life-history is similar in many ways to that of the Acridiidae but the eggs instead of being laid in capsules or pods are laid singly in the soil.

The species of grasshoppers which have shown themselves capable of increasing in numbers sufficient to cause material harm to agricultural crops, are about fifteen in number, twelve belonging to the Acridiidae and three to the Tettigoniidae. The list given herewith places the species in their order of comparative abundance based upon the records made during the past five years, in the "dry belt" region of British Columbia. The species that have occurred in the form of outbreaks are marked with an asterisk. *Melanoplus femur-rubrum* (De Geer) may be added to the list if coastal sections are included, and *Melanoplus packardii* Scudder, if cognizance is taken of the orchard land in the southern Okanagan. These two species are not likely to occur as major pests of the cattle ranges and thus no detailed mention of them has been made.

ACRIDIIDAE

*1. *Camnula pellucida* (Scudder).
2. *Xanthippus neglectus* (Thomas).
3. *Trimerotropis monticola* Saussure.
*4. *Platybothrus brunneus* (Thomas).
5. *Melanoplus infantilis* Scudder.
*6. *Melanoplus mexicanus atlanis* (Riley).
7. *Spharagemon aequale* (Say.).
8. *Metator nevadensis* (Bruner).
9. *Melanoplus bruneri* Scudder.
10. *Bradynotes chilcotinae* Hebard.
11. *Amphitornus nanus* Rehn and Hebard.
12. *Aerochoreutes carlinianus carlinianus* (Thomas).

TETTIGONIIDAE

*13. *Anabrus longipes* Caudell.
14. *Peranabrus scabricollis* (Thomas).
15. *Steiroxys trilineata* (Thomas).

LIFE-HISTORIES AND HABITS

THE ROADSIDE GRASSHOPPER, *Camnula pellucida* (Scudder)

This grasshopper is by far the most common species found on the cattle ranges of British Columbia. It outnumbers all other species many times and it has been responsible, mainly, for the serious outbreaks of the past in which grain, hay, and range grasses have been destroyed. It is interesting to note that alfalfa is only occasionally attacked. In many sections of Canada it is commonly known as the roadside grasshopper from its habit of selecting roadsides and fence rows for egg-laying. In some parts of the western United States it is referred to as the warrior grasshopper but in British Columbia it might

Fig. 9—Female of *Camnula pellucida* (Scudder). × 2. (Original)

aptly be named the range grasshopper. For the sake of uniformity, however, *Camnula pellucida* (Scudder) will be referred to as the roadside grasshopper, if by so doing we understand that the species normally selects dry, uncultivated, depleted sections of land for egg deposition, such as are found along roadsides and on bare open ranges.

THE EGG. The eggs are laid in regular order, side by side, in small compact masses or egg pods in the soil. These egg pods may vary considerably in size

and in shape. Usually the female grasshopper will lay two egg pods and an occasional third at an interval of a few weeks apart during July, August or September. Examination of a number of egg masses in British Columbia showed that the first egg pods deposited contained from 18 to 25 eggs, and the second one from 10 to 20 eggs, an average of 37 eggs per female. The egg is yellow in colour when freshly laid but turns a light brown after a few days. It measures about 4 mm. by 1.5 mm., is bluntly rounded at the ends and slightly curved in shape.

Very few eggs are laid in the main range sections of British Columbia before July 1, the main oviposition period being between the last week of July and the third week of August. During September egg-laying noticeably declines, but a few late-maturing females may still be observed laying eggs as late as October 1. The winter is passed in the egg stage, all adult males and females dying in the autumn months. The eggs hatch in the spring, the maximum period of emergence usually being between May 15 and June 1. The egg stage, thus, is about nine months.

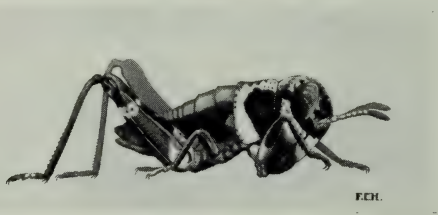


Fig. 10—First stage nymph of *Camnula pellucida* (Scudder) × 8. (Original)

The Nymph. First stage nymphs do not show much colour variation. In general, they are dark grey, almost black, sometimes a rich dark purple and black, with a broad conspicuous oblique white stripe on the sides of the head and thorax. In later stages the nymphs are subject to a great variety of colour pattern and the conspicuous white stripe so characteristic of the small nymph becomes less apparent. The great majority of the nymphs throughout all their stages remain darker in colour than the nymphs of other commonly associated species of grasshoppers of the range. When a large swarm of *Camnula* nymphs is examined colour varieties may be seen which vary from light straw yellow to black through intricate combinations of yellow, grey, and dark purple. These colour variations become more conspicuous as the nymphs approach maturity.

The roadside grasshoppers hatch from the eggs more or less at the same time of year and this almost simultaneous hatching is characteristic of the species. During the season of 1920 the spring was exceptionally late in the Chilcotin district and all growth was retarded from two to three weeks. The first nymphs to appear at Riske Creek in that year were seen on June 1. It so happened that June 3 and 4 were the first really warm days of the year, and a very heavy emergence took place on these two particular days. It was estimated that about 25 per cent of the eggs hatched between June 1 and 5, inclusive, the egg beds and surrounding area being literally carpeted with small dark nymphs. By June 16, about 90 per cent of the eggs had hatched and many nymphs were in their second stage. On July 5, a month from the first hatching dates, the first adult was seen. At this time few nymphs could be found except those in their third and fourth stages; a few very small nymphs were present, however, evidently resulting from eggs laid in the late autumn of the previous year.

In 1921, egg beds in exactly the same area, in the Chilcotin district, were again under observation. The spring was a normal one and hatching, commencing on May 15, became very rapid on the succeeding days, so that ten days

later, on May 24, it was estimated that from 80 to 90 per cent of the eggs had hatched. On June 11, the majority were in their third and fourth stages, and on June 16, a month after the first period of hatching, the first adults were seen.

In 1922, observations were made in the Nicola valley at several scattered points and it was noted that the hatching dates of eggs situated in warm sheltered valleys, such as those around Nicola lake (2,020 feet), were somewhat earlier than those on the more exposed hills surrounding Douglas lake (2,600 feet), or the still higher areas between Minnie lake and Aspen Grove where the elevation, at many points, exceeds 3,500 feet. This variation is perfectly natural as the date at which the snow disappears in the spring, and the warming of the soil, bears a direct relation to elevation and slope. At Douglas lake, in 1922, in sections intermediate between Nicola lake and Aspen Grove, eggs commenced hatching on May 14, and, as was observed in the Chilcotin district, a great proportion of the eggs hatched during the next few days. By June 3, 90 per cent of the nymphs had appeared, and by June 13, again one month after the first date of hatching, the first adults were seen.

From these observations it is clear that the average nymphal period is from four to five weeks, and that the majority of nymphs have emerged from the eggs, in a normal year, by the middle of June. Hatching of eggs, however, continues throughout July, and a very occasional freshly emerged nymph may be seen as late as the end of August.

For a few days after emergence the young nymphs remain more or less on or around their egg beds. When only a few days old, however, a strong tendency to migrate sets in among the swarm, and enormous numbers of first and second stage nymphs may be seen steadily hopping and crawling in one direction. If the egg bed is situated on a gravel ridge, as is quite often the case, this migration is invariably towards green vegetation located at some low-lying spot. So far as our observations go there is no tendency to migrate in the direction of sunlight. Green vegetation alone appears to attract them and it has been observed that even when this is located at some considerable distance, a direct line is taken to this green food regardless of the sun's direction or any objects that may be in their path. This habit of the first and second stage nymphs may be of considerable value at times when considering control measures, as a small ditch of running water between the egg beds and the green vegetation may serve as a trap to the advancing nymphs, which hop in and are swept away and drowned. An open ditch made by a plough or a spade would serve a similar purpose provided it is deep enough, and the soil of a consistency that will prevent the young nymphs crawling up the outer edge.

On the range the food of the young nymphs consists entirely of grass. In mixed farming sections they will attack grain and garden crops. Feeding takes place only on warm bright days; on cold days they remain quiescent and hide away in cracks in the earth or under any loose object on the soil surface. The main feeding period of the day is between 9 a.m. and 4 p.m., and this applies to nymphs in all stages of development and to adults. These points are of some significance in those sections where poisoned bran baits are employed in control.

The Adult. We have noticed that the emergence of the nymphs from the eggs is coincident approximately with the first bright, really warm days of spring, and that the first adults commence to appear about four to five weeks later. We have also observed that the great majority of the eggs have a short hatching period. This applies, somewhat, to the appearance of the adults as well. In 1920, less than one per cent were adult on July 5. On July 15, 25 per cent were adult; on July 25, 75 per cent; and by August 10, all but a few stragglers were in the adult condition. In 1921, the first adult was seen on June 16; on July 2, 25 per cent were adult; by July 10, 75 per cent and by July 30, all but a few were flying.

In 1922, the extremely severe outbreak that occurred rendered the separation of nymphs difficult. The hatching dates over innumerable egg beds, existing at different altitudes, soon caused a mingling of nymphs and adults. At Douglas lake, however, 25 per cent were in adult stage on June 22, the first being seen on June 13. On July 4, 75 per cent were adult and on July 26, few nymphs were to be found.

In an average year the period of maximum abundance of adults would be from the third week of July to the third week of August. After the end of August cool nights and occasional frosts on the areas over 4,500 feet in altitude begin to destroy the adults. Many males die on the breeding grounds after mating. After the middle of September the numbers of adults usually decrease rapidly, the numbers present depending primarily upon the weather. Pairing and oviposition commence in the middle of July, reach their height during the first two weeks of August and decline during September. The sexes of this species are very similar; the males are somewhat smaller and usually considerably lighter and more yellowish in colour. Occasionally females may be found with a deep rose-coloured tint on the head, prothorax, and tegmina; in size they vary from 25 mm. to 30 mm. Specimens collected in Vancouver, B.C., and Victoria, B.C., on the Pacific coast, particularly those found along the seashore were markedly smaller and much brighter in coloration; a difference in length of 8 mm. being found between interior dry belt specimens and coastal forms.

Habits of Adults and Nymphs. The most noticeable habit of this species is that of migrating in swarms. We have observed the first migrating tendency of the young nymphs to travel from their egg beds in any direction to the nearest green food. After the majority of these young nymphs have remained in the grassy depressions on the range or in hay meadows for about a week, their size materially increases. A second migratory tendency then sets in. This appears to be one in which individual swarms tend to move away from their former egg beds and is continuous until the adult stage is reached. In a normal year when grasshoppers are present in ordinary numbers many adults return to their former breeding grounds which are selected for specific reasons. Gravel ridges, dry knolls, depleted grasslands, edges of lakes, or land trampled bare by cattle are favourable egg-laying grounds. When an outbreak occurs the same tendency to move away from their egg-laying areas is in evidence but to a much more marked extent. The tendency appears to be one which will avoid overcrowding and only a small percentage of the adults return to their original breeding grounds. The development of an outbreak of the roadside grasshopper in British Columbia may be compared to the rings produced on the surface of a pool of water when disturbed. This is well represented by the conditions which existed in the Nicola valley during the outbreak of 1921 and 1922.

In 1921, the range around Minnie lake (fig. 11) was heavily infested with this grasshopper and, by August, swarms had spread out over a fifteen mile circle. Enormous numbers of eggs were laid on newly selected breeding grounds around Douglas lake to the northeast, Aspen Grove to the south, and Quilchena to the northwest as well as around Minnie lake and the intervening territory. In the spring of 1922, few nymphs were found hatching outside of this area. During July and August, however, the migrating nymphs and flying adults, having entirely devastated the area within the fifteen mile circle, spread out about another fifteen miles. They reached Chapperon lake and Fish lake to the north of Douglas lake, and continued due west down the valley of the Nicola river, laying their eggs in great numbers around Nicola, Merritt and at other points down the valley. To the south and east the migrating swarms encountered rough timbered mountains, but the nymphs continued on and were seen in great numbers in the thick timber and mountain meadows. These localities were entirely unnatural to them, and many developed into small undersized adults. An examination of the 1921 egg beds showed that only a few eggs were

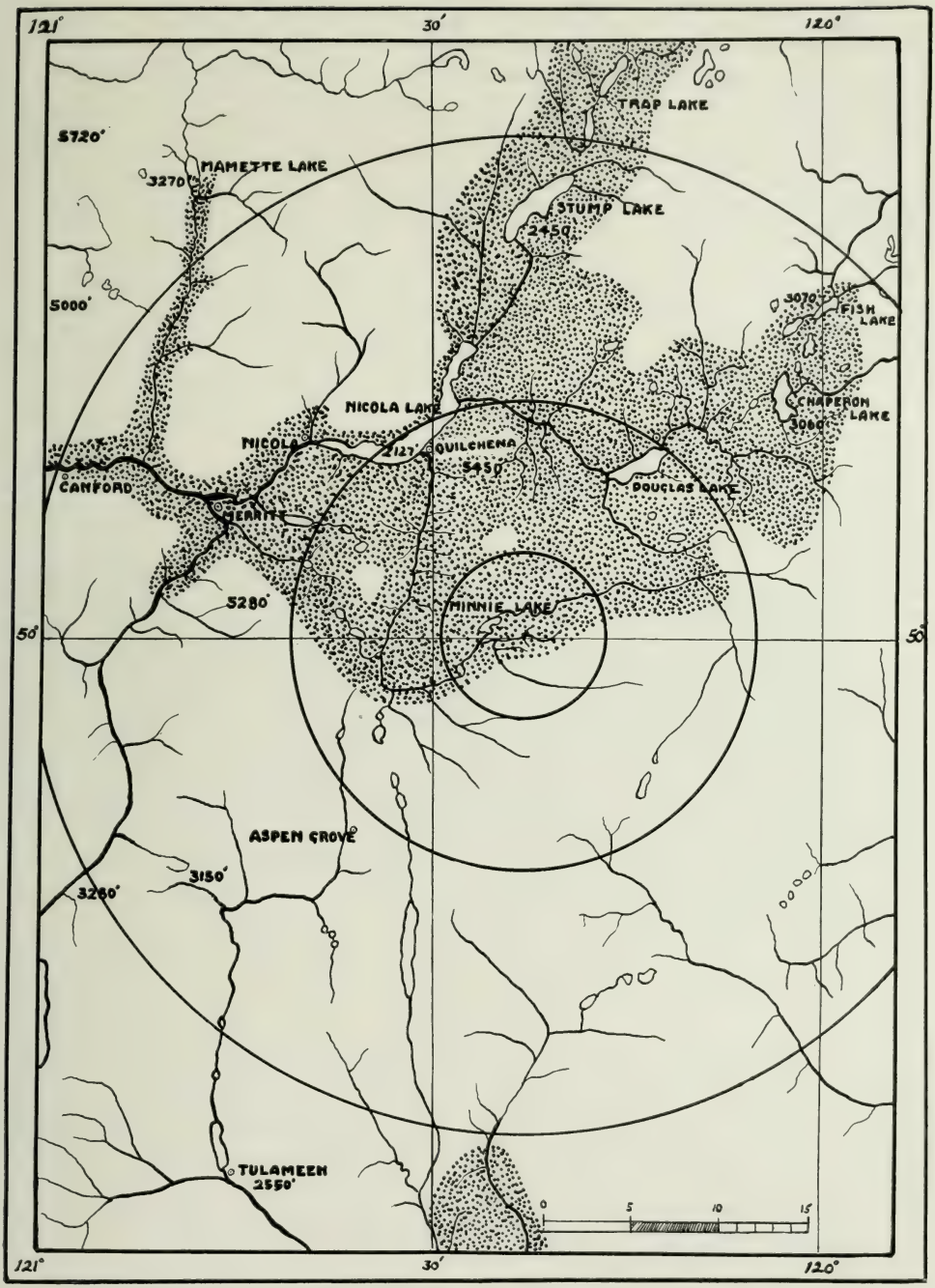


Fig. 11—Map showing the areas infested with the roadside grasshopper in the Nicola valley in 1921, 1922 and 1923, represented respectively by circles.

laid in this same ground in 1922, the majority of the eggs being laid in the new territory. During 1922, at least one half of the migrating grasshoppers reached the limits of the open grass range and passed on into the timbered mountains. Here many were killed by frost before ovipositing and probably only a few found suitable breeding grounds. Eggs laid in these mountain slopes remain unhatched until late July of the following year and few reached maturity before the early frosts of autumn. This habit of spreading out from main breeding areas, involving 15 to 20 miles each year, until the swarms leave the open range and pass into the mountains, has been noticed on other occasions during outbreaks, and the same will undoubtedly occur again in the years to come in all range sections of British Columbia, as long as *Camnula pellucida* (Scudder) remains the prevailing species.

The severe outbreak of grasshoppers in the Nicola valley in 1922 deserves detailed mention not only because it represents what may happen on a depleted range in future years, but also as it records what did happen in 1922. Migrating swarms of nymphs were seen coming off the dry range areas, and crossing the main roads in countless numbers. In many instances, separate swarms of nymphs covering an area of a quarter of a mile in width were observed crossing roads from 8 a.m. until 6 p.m. for a week at a time; a continuous stream of crawling and hopping nymphs.

Irrigation ditches in some places became completely blocked by their bodies. When the adult stage was reached, winged adults were never seen to fly in dense clouds but rather in a steady continual drift, all going in the same general direction for weeks, flying backwards and forwards like a swarm of bees. The migrating adults came in a westerly direction from the high land around Minnie lake and Aspen Grove and passed through the town of Merritt during July. Their numbers were beyond estimation and resembled a thick snowstorm, the individuals appearing as minute shining specks flying from the ground to a point as high as a powerful set of field glasses could detect them. The main swarm passed through Merritt between July 23 and July 31, many remaining to deposit their eggs around the town. When a heavy cloud covered the sun the majority were observed to settle at once on the ground, only to start off in flight again when the sun reappeared. The greatest activity was in evidence between 11.30 a.m. and 4 p.m. and an average distance of three miles was covered each day. This continuous drifting tendency gradually populated suitable breeding grounds.

The roadside grasshopper is almost silent in flight, only a slight buzzing sound being noticed when large numbers are in the air. The flight is swift and direct, without any dodging zig-zag motion so noticeable in many allied species. During the night this species will congregate, if possible, beneath flakes of dry cattle manure or under any loose pieces of wood or stones lying on the range, or in the interior of hay cocks in meadows. Great numbers will squeeze under these shelters, often being found lying on their sides in compact layers. This species is, further, very easily alarmed, and usually will leave the ground six feet in front of an intruder, and will fly from 20 to 100 yards or more before realighting. During August, while the air was still full of flying adults, the tendency to migrate abated considerably, and it was noticed that they flew back and forth over the area selected for oviposition and feeding. At all times of the day during the breeding season the gravel flats and ridges, alkaline patches and lands sparsely clothed with short dry grass (fig. 12) selected as egg-laying grounds showed an overwhelming number of males, their bright yellow bodies being in marked contrast to the dark soil. In the hay or grain fields adjoining, chosen for feeding grounds, fully 90 per cent of the adults were females. During the heat of the day females could be seen flying in from the adjoining feeding areas, alighting on the breeding grounds. The males apparently are able to sense the presence of a female a yard or so away while approaching in the air. When the female has alighted several males immediately make their way towards

her. Sometimes a severe fight among the males takes place and a distinct squeaking and scraping sound is heard as legs and wings rub against one another. If the female has already mated on an earlier occasion she at once begins to search for a suitable spot to deposit her eggs, which is usually against a large stone or among grass roots. With a spot located she raises herself as upright as possible by means of her fore legs and commences to drill down into the soil with her ovipositor. The males, sometimes to the number of from four to seven, continue to push and struggle with one another, and may be seen clinging to the sides and back of the female throughout the egg-laying period which usually lasts about half an hour. These little bunches of grasshoppers are familiar sights on the breeding grounds and form conspicuous objects. After the eggs are laid the female returns to the fields again to feed. The number of ovipositing females at any one time on the egg beds was never very great. Fully from two to three weeks elapse between the laying of the first and second egg pods. In the interval the female feeds voraciously in grain and hay fields, often at considerable distances from the egg beds. Our present observations seem to indicate that the males rarely leave these breeding grounds during the weeks in which oviposition is at its height, and many die there.

Fig. 12—A typical view of a badly overgrazed pasture. Such situations are chosen by the roadside grasshopper for oviposition. (Original)

The food of the roadside grasshopper consists mainly of grasses and grain. When gardens are invaded, onions, lettuce, cabbages and peas are readily devoured, while potatoes and beets are left until other vegetables are all eaten. The foliage of shrubs and trees such as poplars, juneberries, etc., are sometimes attacked during a severe outbreak. Alfalfa and certain weeds such as Russian thistle and dandelion are left untouched, so far as our observations go.

Xanthippus neglectus (Thomas)

(Plate 1, fig. 3)

This grasshopper, which alone has never caused serious damage in British Columbia, is nevertheless of considerable importance. It has been found consistently common throughout the entire "dry belt" of the province during the past five years, its normal habitat being the open dry range, although it has been found in considerable numbers on the bunch grass winter ranges. Its numbers in years when the roadside grasshopper is scarce often excites wonder,

and it is even possible this species is the natural means of maintaining parasites and an even distribution of predatory life on the range. It is interesting to note that dipterous parasitic larvae have been found in early spring (May) in the body cavities of those forms which had overwintered as nymphs.

Trimerotropis monticola Saussure

(Plate 1, fig. 2)

This grasshopper has very similar habits to *Xanthippus neglectus* (Thomas), and the two species occur in association over the entire "dry belt" of the province. It is, however, never found in light timber or in dense brushy ravines and seldom occurs in good stands of bunch grass. It is more restricted to the open plains (fig. 7) than *X. neglectus* (Thomas), and its ideal habitat is found on the dry stony ridges on the higher portions of the range. In a suitable environment it occurs in considerable numbers and has attracted attention more than once on badly depleted portions of the open range. As its habitat is more specific than that of *X. neglectus* (Thomas) it is consequently less evenly distributed over range sections.

During the oviposition period in late July, large swarms of both sexes may be found on the hard, sunbaked, stony slopes of the open range. A typical breeding ground is seen in fig. 7. Living as it does in this particular type of habitat this species is seldom, if ever, attacked by fungous diseases. Migration never occurs, even in years of drought, into neighbouring timber as often takes place with other typical range-frequenting species. Sarcophagid flies, particularly *S. opifera* Coq., frequent the feeding grounds and freely attack the species; in fact this grasshopper is a very important host for such parasitic flies on the open range.

Platybothrus brunneus (Thomas)

(Plate 1, fig. 1)

This species is of peculiar interest for the reason that when it appeared in the Chilcotin district in 1920 it represented an example of a hitherto almost unrecorded somewhat rare species which suddenly became of economic importance when the right environmental conditions presented themselves.

Previous to 1919 the cattle ranges of the Chilcotin area undoubtedly carried a normal complement of grasshoppers of which, doubtless, *Platybothrus brunneus* (Thomas) formed a very small and minor part. It was unquestionably associated with the roadside grasshopper, *Camnula pellucida* (Scudder), *Xanthippus neglectus* (Thomas), and the other native species.

An examination of the range in 1920 showed that about 50 per cent of the grasshoppers present were *P. brunneus* (Thomas), while the roadside grasshopper, *Camnula pellucida* (Scudder), constituted only 30 per cent, the remaining 20 per cent being made up of *Xanthippus neglectus* (Thomas), *Trimerotropis monticola* Saussure, *Melanoplus mexicanus atlanis* (Riley) and a few others. This relative degree of abundance was important as it demonstrated that a species which normally inhabited flat, often alkaline, ground clothed with a dense mat of short-growing grasses, found the open range, which a few years before, supported a stand of tall grass, a suitable environment for multiplication. Full advantage was taken of the evident depletion of the range with the result that an outbreak occurred. These observations are of particular value as they indicate that range depletion, caused primarily by injudicious cattle grazing, will bring into prominence species of insects which are usually considered uncommon.

Platybothrus brunneus (Thomas) is very resistent to frost. In 1920, 10 degrees of frost on August 31 and September 1, followed by several days of heavy rain apparently did not cause any decrease in its numbers. It is

also peculiarly immune to fungous diseases. In 1920, in August, when the range grasses were shrivelled and dry, enormous numbers of *P. brunneus* (Thomas) and *C. pellucida* (Scudder) were observed in some soft damp grass at the edge of a wild hay meadow. *C. pellucida* (Scudder) was found dying freely, both in the nymphal and adult stages, from the fungus *Empusa grylli* Fres., fully 90 per cent being affected, and as many as eighty dead specimens to the square foot being counted on the grass. *P. brunneus* (Thomas) was present at the rate of from 80 to 100 to the square foot but not a single specimen could be found either dead or affected with disease. Fortunately this species which appears to be so hardy did not occur in any material numbers in 1921 or 1922 in either the Nicola or Chilcotin localities where it is known to be present.

Melanoplus infantilis Scudder

(Plate 3, fig. 10)

This small gray species does not vary much in size. It is evenly distributed over the open cattle ranges of British Columbia from the Chilcotin district to the Nicola-Princeton sections on ranges above 2,000 feet in elevation. It has been extremely common in these areas during the past few years, at no time, however, being found in large numbers but scattered thinly throughout large open-range areas. The normal habitat is similar to that chosen by *Trimerotropis monticola* Saussure (fig. 7) as the species frequents bare situations, preferably stony or very gravelly ground for feeding and egg-laying. This species never enters the timber or ravines and is found seldom, if ever, in well preserved bunch grass pastures.

The Lesser Migratory Grasshopper, *Melanoplus mexicanus atlanis* (Riley)

(Fig. 13)

This grasshopper, although not found doing any material damage on the open cattle ranges of the province during the past five years, is, nevertheless, next to the roadside grasshopper, *Camnula pellucida* (Scudder), the species most to be feared in British Columbia. Past records in the province, and state

Fig. 13—Male of *Melanoplus mexicanus atlanis* (Riley) × 2. (Original)

ments from the central prairies of the United States and Canada, where outbreaks have occurred, clearly indicate the potentialities of this species as a pest of first magnitude to orchards, vegetables, garden, grain and alfalfa fields if given the right environment. The lesser migratory grasshopper is able to exist admirably under varied conditions. Herein possibly lies the main reason for its regard as a major pest—its adaptability. It is recorded with its "geographic

races" over the entire province. It occurs commonly on Vancouver island, in the Lower Fraser valley, throughout the entire interior "dry belt," in the Kootenay lake sections, and in the eastern mountainous regions of British Columbia. In other words it is abundant at altitudes which vary from sea level up to 4,000 feet; and in sections in which the annual precipitation varies from 15 inches to 70 inches.

In some of the earlier outbreaks of the province, species of the genus *Melanoplus* were recorded in association with *Camnula pellucida* (Scudder) and in this connection both *Melanoplus atlanis* (Riley) and *M. affinis* Scudder, have been mentioned. Largely as a result of the studies of Messrs. Rehn and Hebard it is now believed that the latter two species are synonymous and that *M. atlanis* (Riley), together with *M. bilituratus* Walker, are geographic races of *M. mexicanus* Saussure. Southern and central British Columbia, so far as this species is concerned, are apparently within the zone of intergradation of these two races.

The lesser migratory grasshopper is a very active and powerful jumper, the wings being used to prolong the leap. The wing length is very variable, the long-winged specimens, naturally, being far more powerful fliers than those with shorter wings. There is also considerable variation in the intensity of colouration; the hind tibiae, furthermore, though usually red, are often blue in colour. Unlike the roadside grasshopper, this species in its later nymphal and adult stages is a plant-perching species which means that, wherever possible, the night is spent perched on some tall weed or shrub. It will readily devour almost any kind of garden crop and its perching abilities render it a menace to standing grains. In the outbreak which occurred at Celista in 1919 it showed partiality for cruciferous plants, grain and onions, and only attacked beets and potatoes when forced to by lack of food. To indicate the diversity of feeding habits, it may be mentioned that the adult grasshoppers made their way into the houses of the settlers and ate holes in the window curtains, tablecloths, bed-covers, clothes and cardboard boxes holding household provisions. It is recorded in the past that alfalfa has been attacked by grasshoppers. It is probable, however, that when such occurred the lesser migratory grasshopper and other species of *Melanoplus* were at fault. Injuries to the bark of apple trees and defoliation of fruit trees is also more often attributable to species of *Melanoplus* than to any other genus.

The lesser migratory grasshopper deposits its eggs in firm soil beside cattle trails and paths and in the open spaces between clumps of grass but not amongst the roots of the plants as is usually the case with the roadside grasshopper. In settled sections old worn-out alfalfa fields or hard grain stubble are favourable places for the egg-laying of this species. On the open cattle range it does not congregate in any given area or assemble on definite egg beds to the same extent as *Camnula pellucida* (Scudder) but suitable places for egg deposition are usually found scattered over large sections of the range. When outbreaks occur nymphs are evenly scattered over the grass lands from the moment of hatching, and, thus, at the outset, are not so noticeable as the localized swarms of *Camnula pellucida* (Scudder). There are from 12 to 30 eggs deposited in a single egg pod at one time, and, probably, as with the roadside grasshopper, two egg pods are laid by each female. The nymphs begin to hatch in the middle of May and continue to do so throughout June and July, a few still emerging as late as August. From our observations during the past five years it would appear that, in general, the nymphal period in the genus *Melanoplus* is about six weeks, or from ten days to two weeks longer than is usual for the members of the Oedipodinae to which the genera *Camnula*, *Trimerotropis* and *Xanthippus* belong. The earliest adults are seen about July 10, and 75 per cent are usually full grown during the first week in August. They are at their height and, if numerous, very prominent, during August and September, and adults may be found throughout October and often until the middle of November, if the

autumn frosts have not been too severe. Mating of the sexes, and oviposition, may be commonly observed during August and September.

Bearing in mind the normal oviposition habits of the lesser migratory grasshopper, it is interesting to recall that the primary type of vegetation on a cattle range is bunch-grass. This grass grows in clumps and does not permit other grasses to occupy the intervening spaces (fig. 6). A typical bunch-grass prairie may, therefore, be pictured as a plain, lightly covered with hillocks of grass growing normally fifteen inches to two feet in height, an environment particularly suited to this species, the grasshoppers ovipositing between the clumps of bunch-grass, resting and feeding on the seed heads and leaf blades.

Attention has been drawn to the secondary type of vegetation on a cattle range, following the destruction of bunch-grass. A closer mat of grass of mixed varieties, of equal if not better feeding value, becomes established. Such an environment is not so well suited to the lesser migratory grasshopper, but becomes more attractive to the roadside grasshopper, particularly when these secondary grasses are kept short by cattle grazing. This probably explains why *M. mexicanus atlanis* (Riley) has not been very prominent of recent years, less prominent than it was in earlier years, and, so far as the cattle ranges of British Columbia are concerned, of less importance today than *Camnula pellucida* (Scudder). The character and the condition of the vegetation predetermines the nature of a grasshopper outbreak; the species and prevalence of the grasshopper indicates the condition of the range. It is possible that a neglected dry farming region bordering upon a range area where weeds such as tumbling mustard and Russian thistle have become established, might provide a suitable environment for the lesser migratory grasshopper and produce a nucleus for a local outbreak.

The lesser migratory grasshopper is subject to the attacks of parasites, sarcophagid flies being commonly known to attack this species, their larvae having been found within the bodies of the host.

Spharagemon aequale (Say)

(Plate 2, fig. 8)

This grasshopper has never been found in British Columbia in any great numbers on open or overgrazed range areas, which have thus far formed the chief habitat of the species already mentioned. It is most commonly found, however, in the sheltered valley slopes and benches of the "dry interior," delighting in warm locations where good stands of the original bunch-grass still remain (fig. 2). In these situations it finds its ideal home where it forms, especially on the bunch-grass winter ranges, one of the chief species of economic importance. This is of particular interest in that it indicates the possibilities of the species becoming a pest on a re-established or well-regulated range. In 1921, in conjunction with *Metator nevadensis* (Bruner), a species with a similar habitat, this grasshopper caused appreciable damage to the bunch-grass on the lower fenced winter range areas of the Chilcotin valley.

It will only be of importance, however, in restricted areas, its distribution being guided by apparently very clear altitude limits. In British Columbia only an occasional specimen has been taken at elevations exceeding 2,500 feet and it has been found most abundantly in the lowest localities in the dry belt at altitudes of from 900 to 1,500 feet. Thus, it will only be of importance on the lower ranges of the Okanagan, Similkameen and Thompson valleys, on the stretches between Kamloops and Spence's Bridge, and along the lower benches of the Chilcotin and Fraser rivers. It is almost entirely absent from the main winter and summer cattle ranges throughout the Nicola valley from Princeton to the high ground immediately above and south of Kamloops and from the main areas in the Chilcotin district.

The moderately swift, low-flying habit of the female appears to be especially attractive to sarcophagid flies, as these beneficial insects may frequently be seen in action, their larvae being commonly extracted from the bodies of captured females.

Metator nevadensis (Bruner)

(Plate 2, fig. 6)

This species, with *Spharagemon aequale* (Say), is an inhabitant of normal bunch-grass areas. At the present time it is chiefly found amongst the bunch-grass stands on the river benches, particularly on the Riske Creek winter ranges, but it may still be found in small numbers all over the range sections of the dry belt from the Chilcotin district to the Okanagan valley. Its occurrence over these range areas seems to indicate that at one time it existed there in considerable numbers as there is little doubt that it is a species whose normal habitat has become much restricted following the destruction of the normal bunch-grass stands by overgrazing. During the summer of 1921, it was extremely common on certain winter ranges in the Chilcotin district and in the future it may become, with *Spharagemon aequale* (Say) a pest of some importance on re-established second growth ranges.

Bruner's Grasshopper, Melanoplus bruneri Scudder

(Plate 2, fig. 5)

This grasshopper and *Bradynotes chilcotinae* Hebard, were the most common and injurious species in the lightly timbered areas of the summer range in the Chilcotin sections during 1920 and 1921. They live normally among rank-growing grasses and plants growing under the aspen poplar groves which often form belts separating the open range from the timbered hills. Here in such an environment they may cause material damage. In 1920 and 1921 these two species became very numerous and advanced into the open glades and small mountain meadows where vegetation was thick and green. Both species appear to find their natural habitat on the higher summer ranges of the Chilcotin areas and have not been noted elsewhere in injurious numbers.

Bradynotes chilcotinae Hebard

(Plate 2, fig. 7)

This wingless grasshopper was described by Mr. Morgan Hebard in the Transactions of the American Entomological Society, Vol. 48, p. 58, 1922, from material collected in the Chilcotin district of British Columbia, where it was very common during 1920 and 1921. *Bradynotes chilcotinae* Hebard, together with *Melanoplus bruneri* Scudder, in the above years, caused material damage to vegetation under the poplar trees that fringe the edges of the open range. Both species frequent situations that are partially shaded, being found in some numbers in the mountain meadows on the Riske Creek and adjoining ranges.

Adult specimens have been found with their body cavities containing dipterous larvae. In one instance five parasitic larvae were found within the thoracic cavity of a single female.

Amphitornus nanus Rehn and Hebard

(Plate 3, fig. 11)

This small species is mentioned only because it forms an integral part of the grasshopper population of the open range, but it will probably never become injurious enough to be of economic importance. During the past five years this species has been present in slightly varying numbers, evenly scattered throughout the entire dry belt from the Chilcotin district to the international

boundary. In the Okanagan valley its place is apparently taken by a closely allied species, *Amphitornus coloradus* Thomas, doubtless a geographic race of the same species.

Aerochoreutes carlinianus carlinianus (Thomas)

(Plate 1, fig. 4)

This species is, also, found commonly on the Riske Creek and Nicola ranges. Its normal habitat (fig. 14) is on the driest and barest ridges, and it is only found

Fig. 14—A severely overgrazed winter range. Photograph taken in July. A typical habitat of *Aerochoreutes c. carlinianus* (Thomas). (Original)

in numbers on the open range where depletion due to overgrazing is severe. Unquestionably this species has benefited greatly by the overgrazing of the range, and serves as a useful indicator of the latter's condition.

Anabrus longipes Caudell

(Plate 3, fig. 12)

This large species is always liable to a sudden increase in numbers over certain areas. Only once to our knowledge, however, has it increased sufficiently to do any very marked damage in British Columbia and this was when it occurred in outbreak form in 1911 on the range land to the west of Vernon in the north Okanagan valley.

During the past few years it has never been noticed in great numbers although it has a wide distribution throughout the interior of the province and it may be found in the most arid sections of the southern Okanagan valley to the timber in the mountains. It is as much at home on sage brush flats as in cool, damp mountain meadows. It prefers to live close to cover of some sort and on the open ranges, is usually found in brushy ravines and around poplar clumps. It is, however, particularly abundant on the lower mountain slopes and in open glades between belts of light timber (fig. 15). Its near relative, *Anabrus simplex* Haldeman, the western or mormon cricket, a few specimens of which have been taken in the Okanagan valley, has caused great damage at times in the western United States. The potentialities of these two insects as pests of the open range must be acknowledged.

The Coulee Cricket, Peranabus scabricollis (Thomas)

The coulee cricket was not known to occur in British Columbia until 1922 when several small colonies were found upon the cattle ranges of the Nicola valley. These colonies contained only a few individuals and were not discovered until all were in the adult condition. The inclusion of the species here constitutes an original record and is chiefly of interest from this standpoint. Few notes on their habits in British Columbia have been obtained.

Fig. 15—A typical habitat of *Anabrus longipes* Caudell in the Nicola valley, B. C. This illustration also shows typical summer range in the higher altitudes. (Original)

It is very important that this species be watched as in the state of Washington it has proved itself capable of increasing very rapidly until countless millions appear which later migrate across country destroying grain and cultivated crops in their wake.

Steiroxys trilineata (Thomas)

(Plate 3, fig. 9)

This species is found in similar locations to *Anabrus longipes* Caudell, being an inhabitant of the grassy gullies of the open range, the poplar belts, and the mountain glades from the lower slopes to the timber line.

It is an extremely active species, with very long hind legs which enable it to jump comparatively long distances. When pursued it is an erratic jumper, leaping and dodging about amongst the vegetation which makes it difficult to capture. It is not likely to become injurious, but its numbers and its presence

in the grassy gullies of the open range make it a noticeable feature of the orthopterous fauna of range sections. It is a possible carrier of parasites, though, thus far, only hair-worms have been found in the body cavities of this species.

NATURAL CONTROL FACTORS

A glance at the chart (fig. 4) on page 7, demonstrates that grasshopper abundance on the range sections of British Columbia has occurred in periodical cycles, and at more or less definite intervals. This condition is well known to those who are familiar with the circumstances, and it has taken place as a natural event not interrupted or influenced by the application of artificial control operations. That is to say, the declines of grasshopper abundance have not been occasioned by human agencies but have occurred as natural sequences following the interplay of natural controlling factors. In gardens, on ranch meadows, and in cultivated grain or hay fields, grasshoppers may be controlled by the judicious use of poison baits, by artificial barriers or, in some cases, by cultural operations. On the open range similar measures could only be practised with difficulty. Consequently, realizing the importance of natural controlling factors it is desirable that as complete an understanding as possible be obtained of them to determine the practicability of their utilization to modify anticipated outbreaks. While certain artificial control measures may be employed on the open range to lessen the severity of an attack it must be fully realized that the fundamental problem of control is to regulate range management so that the most value is obtained from the factors which bring about natural declines in grasshopper abundance.

Climate. It has already been pointed out earlier in this bulletin that it is the open range-frequenting species which are primarily considered to be the most injurious. These species delight in dry, hot, arid conditions. Periods of drought which check the natural growth and reproduction of grasses, and which may entirely destroy the development of those grasses growing in gravelly or sandy places, may provide conditions suitable for egg-deposition in the autumn. If a series of dry years follow one another opportunities are offered for grasshoppers to increase to enormous proportions. The eggs, safely placed in the soil in a compact mass and covered with a substance which renders them waterproof, are peculiarly invulnerable to climatic factors. Furthermore, as will be stated later, there are certain forms of predatory life which frequent the egg beds of grasshoppers, and which devour eggs in plenty. These beneficial agents are active in the autumn and in the spring. Their activities are largely dependent on temperature conditions. Hence it is reasonable to suppose, that if there is an early fall of snow which occurs before the ground is frozen, the activities of these beneficial agents will, to some extent at least, be maintained for a greater length of time than if the soil freezes early and remains frozen throughout the winter. Intense cold has little or no effect on grasshopper eggs.

Variable temperature, however, causing frequent alternations of heat and cold, will unquestionably destroy many eggs, particularly in the early autumn and spring and will doubtless cause a diminution in the numbers of predatory forms of life as well. The depth of snow and the length of time snow lies on the ground will thus bear an intimate relation to the resulting conditions. Rain has little or no effect on the eggs in the early spring; in fact, frequent rains may improve the percentage of emergence. The young nymphs which hatch from the eggs in the spring may nearly all be destroyed by a cold, heavy rain, a fall of snow or by a sudden low drop in temperature. A heavy rain, however, coming late, when the grasshoppers have reached their second or third moult, will not materially reduce their numbers.

As a result of all these factors it may be stated that a series of dry summers and steady cold winters produce conditions which favour an outbreak. A dull wet summer and an open winter has a contrary effect and the numbers of grasshoppers may be reduced materially under these circumstances.

Migration. The roadside grasshopper during the past five years has been the most injurious species of grasshopper on the range. The migratory tendency which allows this species to spread out in all directions from certain localities which are especially adapted as egg-laying grounds, exerts a very powerful influence on the rate of decrease in a grasshopper outbreak. In the case of the Nicola valley outbreak of 1922 and 1923, the original centre of which was the Minnie lake section, the grasshoppers spread out over the surrounding territory in circles widening by about fifteen miles each year. Obviously this movement will ultimately force the grasshoppers into the timbered mountains, and on to the higher elevations of the range, with the result that many will succumb to adverse climatic factors, leaving behind over the infested country a very much reduced infestation. The more severe the infestation the more rapid the migration. The importance of this annual movement must be borne in mind when dealing with an infestation of the roadside grasshopper but it must not be confused with the movements and habits of the lesser migratory grasshopper or other species mentioned in this bulletin.

Parasites. The word parasite as here used means a form of life which lives at the expense of its host. Usually such parasites are other species of insects, sometimes they are internal fungous or bacterial diseases or they may be parasitic worms (*Nematomorpha*). Fortunately there are several parasites which habitually frequent the egg pods and the bodies of grasshoppers. Climatic conditions which affect the development of grasshoppers also affect the welfare of parasites. There is, however, one further observation which should be made in demonstrating the influence of grasshopper parasites in or following an outbreak. All the known insect parasites of grasshoppers are smaller than their hosts and all are unable by themselves to cover the same distances in flight, only a few accompanying a grasshopper when it is migrating in the adult stage. This is an important point which applies not only to the true insect parasites of grasshoppers but to many other predatory forms of life which, with plant parasites and bacterial diseases, are instrumental in controlling outbreaks. We have seen that a hot dry season favours grasshopper multiplication and checks the growth of the native grasses. When such conditions arise, the primary host is forced to migrate and this has a direct bearing on the influence of parasites and predators which can only accompany their host in small numbers. When the effect of a decreased food supply is intensified by cattle grazing this influence is more pronounced. The re-establishment of range grasses would mean a circumscribed feeding area and confined breeding and egg-laying grounds for the grasshoppers, and thus a more even interplay of those forces which normally and naturally affect their numbers.

Sarcophagidae. Some of the most useful of the grasshopper parasites belong to this important family of flies. They are robust, strong-flying insects, often larger and more hairy than the ordinary house-fly, to which they bear a close resemblance. They are commonly referred to as flesh flies for the reason that many members of the group deposit eggs on the bodies of dead animals, and the larvae live commonly in manure and in decomposing animal and vegetable matter.

Those species which appear to be of most service in the control of grasshoppers possess the peculiar habit of depositing live maggots upon the bodies of their hosts. These flies may be seen quite commonly on the open range and their prevalence has attracted attention on more than one occasion. They may be observed sitting alert on short blades of grass or on bare places on the ground.

When a grasshopper passes in flight above them they instantly rise, dart in pursuit and deposit a larva either on the upper side of the abdomen or at the base of the wings. The larva is covered with a sticky substance which enables it to adhere to the body of the grasshopper without trouble. This parasitic larva then commences to burrow into the body of the grasshopper. As is usual with most parasitic larvae the connective tissue, fat bodies and body juices of its host are first attacked while the vital parts are left untouched until the last. In this way the grasshopper is not prevented from feeding and migrating. Ultimately, however, the grasshopper succumbs to the attack but not before it has succeeded in reaching the selected oviposition area, in company with the other specimens of its kind. When fully mature the parasitic larva escapes from the body of the grasshopper, pupates in the soil and ultimately emerges as a fly. These parasites are capable of increasing rapidly in numbers owing to the fact that more than one generation occurs in the year. Apparently they are not particular as to the kind of grasshopper they infest, as individuals of a single species have been bred from many different species of grasshoppers and from members of different insect families. It is certain that dipterous parasitic larvae, not necessarily sarcophagids, are found in April in the bodies of over-wintering nymphs of *Xanthippus*. This is a particularly fortunate event as it doubtless insures the more rapid reproduction of beneficial flies. It also indicates the desirability of having a number of early appearing over-wintering nymphs present on the range to provide parasites for the later appearing and usually more injurious species of grasshoppers which have passed the winter in the egg stage. The value of this point has not as yet been fully determined.

During May of 1923, in the Nicola valley, larvae of *Sarcophaga opifera* Coq. were found feeding upon the eggs of *Camnula pellucida* (Scudder) in the soil. *S. opifera* Coq. was commonly taken in the Chilcotin district in 1920 and 1921, and in the Lower Okanagan valley in 1923, and was observed during these years actually larvipositing on the bodies of adult grasshoppers of various species. It is possible, therefore, that these parasitic larvae after leaving the bodies of their hosts in the autumn, continued their development by feeding on eggs below ground, emerging in the spring as adults. *Sarcophaga hunteri* Hough has also been taken commonly in the adult condition on the ranges around Vernon and Kamloops, B.C., and doubtless possesses similar habits, as according to Mr. Norman Criddle, of the Dominion Entomological Branch, this fly has been reared from larvae found in egg pods of grasshoppers in Manitoba. *S. tuberosa sarracenioides* Aldrich was reared from the western cricket (probably *Anabrus longipes* Caudell) by the late Dr. James Fletcher in 1896, in the Okanagan valley, and as this fly has been bred from various grasshoppers in the United States there is little doubt it is associated with grasshoppers in British Columbia, although our records on this point are meagre.

Tachinidae. These flies are closely allied to the Sarcophagidae. Few authentic records exist as to the species bred from grasshoppers. In 1922, however, two specimens of a tachina fly were reared from a nymph of *Xanthippus neglectus* (Thomas) in the Nicola valley. These flies have been identified by Dr. J. D. Tothill, of the Dominion Entomological Branch, as *Acemyia dentata* Coq., a species which has been bred from *Chortophaga viridifasciata* De Geer. It has been taken at Ottawa, Ontario, in southern British Columbia, at Bozeman, Montana, and, in general, has a wide range in the United States from Massachusetts to California. Riley, in his report on the Rocky Mountain Locust in 1877, states that "there are many which attack the locusts of which *Tachina anonyma* Riley, and *Exorista flavicauda* Riley are the commonest."

Egg Parasites. The hymenopterous egg parasite, *Scelio luggeri* Riley, is recorded by C. V. Riley in 1877 from the Rocky Mountain Locust, *M. spretus*.

Sarcophagids determined by Mr. C. H. Curran, Dominion Entomological Branch.

We are also informed by Mr. Norman Criddle, of the Dominion Entomological Branch, that *Scelio calopteni* Ashm. has been bred from *Melanoplus* eggs in Manitoba. *Sparasion pilosum* Ashm. was furthermore reared from eggs of the coulee cricket in 1917, in Washington state, by Melander and Yothers. Doubtless hymenopterous egg parasites also occur in British Columbia but none have, thus far, been reared.

Fig. 16. A tachinid, *Bonnetia comta* Fall × 4. (After Strickland).
A type of beneficial fly.

Fungi and Bacteria. A fungous disease is a microscopic form of parasitic plant growth. Certain of these growths affect grasshoppers. The fungus gives rise to spores which settle on, germinate, and penetrate the bodies of grasshoppers. Grasshoppers, when attacked by such a disease, climb up the stems of plants and die, where they remain, clinging to the plant at its highest point. Sometimes these parasitic fungi are of considerable importance and, if moisture conditions are favourable, may kill off grasshoppers in great numbers. *Empusa grylli* Fres. has been the most common form found attacking nymph and adult grasshoppers in British Columbia. In 1921, in the Chilcotin district this disease accounted for large numbers of *Camnula pellucida* (Scudder). Curiously enough this disease did not affect *Platybothrus brunneus* (Thomas) which was intimately associated with *C. pellucida* (Scudder) in the outbreak of that year. The difference in the effect of the fungus on these two species was most pronounced. In 1923, in the Nicola valley, a warm wet spell occurring in late June, undoubtedly induced the development of this fungus to such an extent that the outbreak of grasshoppers was effectually checked.

As for bacterial diseases, while they are known to occur, no definite information with regard to them has been gathered during the past five years in British Columbia. With these diseases, as with the fungous diseases, the more circumscribed the grasshoppers are in a given area, the better the opportunity for control. The more widespread the grasshopper infestation the less the opportunity for these diseases to subdue the outbreak.

Hair-worms. It is well known that certain species of hair-worms, belonging to the genera *Gordius* and *Mermis*, infest insects, and in past years they have been recorded from grasshoppers and crickets. Individuals of the species, *Anabrus longipes* Caudell and *Steiroxys trilineata* (Thomas) have been taken in British Columbia, with specimens of *Mermis* within their body cavities. C. V. Riley, in his Rocky Mountain Locust Report of 1877, records *Gordius seta, G. robustus, Mermis albicans* and *M. acuminata.*

Predators. A predatory insect or animal is a form of life which destroys its host by feeding externally. Birds, snakes, mice, shrews, skunks, and coyotes represent, in a broad sense, what may be considered predatory enemies of grasshoppers, as they feed upon and destroy many nymphs and adults. American sparrow-hawks, crows, blackbirds, meadow larks and Columbia sharp-tailed grouse (prairie chickens) are of some value on the cattle ranges of British Columbia. In many cases these birds, feeding on mice, beetles and other forms of life, make grasshoppers only incidentals in their diet. Nevertheless they are valuable allies when grasshoppers are in an outbreak form. Spiders, mites and insects, however, owing to their numbers, and their ability, in many cases, to penetrate the soil in search of food, are chief among the constant predatory factors influencing the numbers of grasshoppers. The following are probably the most important:—

(1) *Predatory Flies.* The Asilidae, or robber flies, represent the most important family of flies which regularly prey upon grasshopper nymphs and adults. There are a large number of asilids in British Columbia and they are particularly abundant in the dry interior sections of the province. The only species actually observed killing and feeding upon nymph and adult grasshoppers are *Stenopogon morosus* Loew, *Stenopogon inquinatus* Loew and *Proctocanthus milberti* Macq., all being noted in the Okanagan and Nicola valleys and in the Chilcotin district. These three species are remarkable for their size, and have been observed on many occasions flying off with live adult grasshoppers and other insects. The asilid while on the wing seizes the grasshopper by means of its long powerful legs and at once plunges its proboscis into the body, usually at the throat, apparently paralyzing it instantly. The fly then alights on a convenient plant and proceeds to suck out the juices from the body of its prey. The general feeding habits of asilids, however, do not render them of much value as controlling agents in a grasshopper outbreak, as they as readily attack members of their own species, while bumble bees, wild bees, wasps and butterflies are not exempt from their attentions.

Many smaller species of asilids also occur which prey chiefly on small bees, flies and young grasshopper nymphs; *Erax rapax* O.S. and *Erax snowi* Hine having been noted in the Chilcotin area, while in the Okanagan valley *Erax harveyi* Hine, *E. rapax* O.S., *E. canus* Hine and *E. aridus* Will., have been observed.

The Therevidae are also predaceous, but, so far as our observations go, only in their larval stages. At Nicola, B.C., in May, 1923, the larvae of *Psilocephala lateralis* Adams were found feeding below ground upon the egg pods of *Camnula pellucida* (Scudder). They were successfully reared and the adults identified by Mr. C. H. Curran, of the Dominion Entomological Branch.

The Sarcophagidae in their larval stages may also be classed as predators on account of their habits of feeding on egg pods of grasshoppers in the autumn and spring. Very minute larvae, particularly those of *S. hunteri* Hough., have been taken in association with grasshopper egg-masses in the autumn in Manitoba according to Mr. Norman Criddle. This condition suggests that the adult flies actually deposited young in the vicinity of the egg pods, although there is a possibility that the sarcophagid larvae were from the bodies of adult grasshoppers which they had left shortly after being deposited.

The Bombyliidae likewise are predaceous in their larval stages, in the nests of various insects, such as wild bees, and upon the egg pods of grasshoppers. The most important species recorded in the egg beds of grasshoppers in British Columbia is *Systoechus oreas* O.S. This species is typically western in distribution and has been commonly taken throughout the Nicola and Okanagan valleys. Its life-history has not been fully investigated but indications point to the fact that often two years are spent in the larval stage. Two other species, *Systoechus vulgaris* Loew and *Anastoechus nitidulus* Fabr. are also recorded

from British Columbia. Neither of them have been encountered very commonly during the past five years, but it is interesting to note on the evidence of Mr. Norman Criddle, that the former species, *S. vulgaris* Loew, in 1922 and 1923 was largely responsible for the subjection of *Camnula pellucida* (Scudder) in southern Manitoba. During these years in Manitoba thousands of adults were seen visiting flowers and larvae were so numerous in *Camnula* egg beds that from fifty to eighty per cent of the egg pods were destroyed.

(2) *Predatory Beetles.* Among the predaceous beetles which chiefly belong to the families Carabidae and Meloidae, are many predatory forms which feed upon the eggs and larvae of many species of insects, including the eggs and nymphs of grasshoppers.

The Meloidae, which include the blister-beetles, are vegetable feeders in their adult stages, while as larvae they are known to feed upon grasshopper eggs. Adults have been reported in many localities in the province as injurious

Fig. 17. The carabid beetle, *Pterostichus lucublandus* Say; much enlarged. (After Gibson and Treherne.)
A type of beneficial beetle.

to alfalfa and potatoes and on account of their injuries to this latter plant they are often erroneously called "Potato Bugs." On the open ranges, the adults of the species associated with grasshoppers, feed almost entirely upon Snowberry, *Symphoricarpus racemosus* Mich., or, in the case of a pale grey species of *Epicauta*, at present undetermined, upon lamb's quarters; *Chenopodium album* Linn., an introduced weed which may be found in the vicinity of ranch buildings and on abandoned dry farms. On many of our ranges *Symphoricarpus* plants are becoming scarce owing to continual grazing, and the absence of the natural food of these important beetles may possibly be one of the factors influencing the increase of grasshoppers on the range. It is customary to associate the numbers of these beetles with the increase and decline in grasshopper abundance. In years when grasshoppers are declining in abundance these beetles become very common, having increased very materially owing to the plentiful supply of larval food present during a grasshopper outbreak. In

British Columbia the species whose numbers seem to fluctuate in this way, and which may be assumed to be predatory in the larval stage upon grasshopper eggs are:—

1. *Pomphopoea aenea* Say. Peachland, Chilcotin; a small dark steel blue species on *Symphoricarpus.*
2. *Epicauta puncticollis* Horn. Similkameen, Osoyoos, Princeton, Chilcotin; a small black species on *Symphoricarpus.*
3. *Epicauta oblita* Lec. Chilcotin, Kamloops; a small black species on *Symphoricarpus.*
4. *Epicauta fissilabris* Lec. Vernon; a small black species on *Symphoricarpus.*
5. *Lytta cyanipennis* Lec. Similkameen, Vaseaux lake, Lillooet, Nicola; a large dark blue-green species on lupines and vetches.
6. *Lytta infidelis* Fall. Vernon, Chilcotin; a small blue-green species on lupines and vetches.

The Carabidae or ground beetles are predaceous both as adults and larvae upon the eggs and young nymphs of grasshoppers. The mature beetles deposit eggs in the soil and the larvae, hatching from them are peculiarly adapted to a free movement through the soil. They readily devour all forms of insect life which they may encounter, and, thus, particularly when present in an egg bed of certain grasshoppers are important factors in control.

The authors are indebted to Mr. Ralph Hopping, of the Dominion Entomological Branch, for the identification of the species found commonly on the ranges of British Columbia, which are as follows:—

1. *Calosoma irregulare* Walker (possibly a variation of *C. tepidum* Le Conte). Vernon, Chilcotin, Kamloops, Nicola valley.
2. *Percosia obesa* Say. Chilcotin, Kamloops, Vernon.
3. *Harpalus fraternus* Lec. Victoria, Chilcotin.
4. *Harpalus somnulentis* DeJ. Spences Bridge.

ARTIFICIAL CONTROL MEASURES

Control Under Range Conditions

After a perusal of the general substance of this bulletin and particularly after reading the remarks made in the section dealing with the causes of range depletion it should be clear that the control of grasshoppers on the range mainly rests on the question of the re-establishment of the range grasses.

Of the Acridiidae listed on page 15, those numbered from 1 to 5, and 12, are species which have benefited by depleted range conditions. Those numbered from 6 to 8, and 11, prefer a situation supporting a good stand of grass such as is found on a protected winter range. The importance of these latter species lies in their stability as regards numbers, and the fact that they represent a uniform type of insect life on the range, having occurred only occasionally in sufficient numbers to cause noticeable injury.

As regards the two remaining species of Acridiidae, numbers 9 and 10, which occur in the fringes of light timber adjoining the open range, their numbers have been observed to increase to such proportions at times as to cause material damage to range grasses and to the vegetation in the mountain meadows. The species that occur on a depleted range are the most likely to prove injurious, hence, measures taken to improve the range also lessen the danger of an outbreak.

Judicious management of cattle within selected grazing limits is the keynote of success in grasshopper control on the range. Range management is an undertaking best left to those concerned and it is not the purpose of this bulletin to deal with that question at all. We must of necessity content ourselves in merely

pointing out that grasshoppers, and other injurious insects of the range, of which cutworms and wireworms may be mentioned, are secondary issues capable of correction by means of range rotations, specific grazing areas, reseeding projects, and such like procedures which are the especial concern of the cattle owners and Government range officials.

Sufficient evidence has been accumulated during the past five years to indicate that providing areas are properly fenced for a series of years, or for definite periods in a year, grasshoppers do not, or even cannot, permanently injure the stand of grass, although in years of outbreak they may severely attack mature grass in the neighbourhood of prominent breeding grounds during July and August.

To secure evidence in this connection, supplementary to the evidence obtained from observations on well-governed ranges, a five acre plot was selected and fenced in 1921. This plot which was situated on the most over-grazed

Fig. 18—Photograph showing the result of protecting heavily grasshopper-infested range from cattle-grazing by fencing during the growing season. Photograph taken in autumn, five months after the fence was erected. (Reproduced by courtesy of the Office of the B.C. Grazing Commissioner, Department of Lands, Victoria, B.C.)

section of the Riske Creek range clothed in a fair stand of second stage vegetation, was within one hundred yards of an alkaline flat where a large egg bed of *Camnula pellucida* (Scudder) occurred. The fence was completed in May after the cattle had grazed over the ground for six weeks. A few weeks later the difference in the character of the vegetation inside and outside of the fence was most noticeable (fig. 18). The growth of the grass was carefully compared with the development of the grasshoppers and it was noticed that the grass on the inside of the fence had completed its growth and had set its seeds before the grasshoppers had all emerged from their eggs. Outside the fence, on the open range, cattle grazed freely, without hindrance. The result showed that the grass did not form as many seed heads on the range, and the leaves had no opportunity to develop or mature. At the end of June and during July, the grass on the inside of the fence was mature, while the grass on the outside, endeavouring to perform its natural function, was continually throwing up small green shoots around

the roots. These tender shoots, if they escaped the attention of the cattle, afforded ideal food for the developing grasshoppers. Both nymphs and adults fed ravenously on these tender green leaves but did not make any effort to enter the fenced area. At the first severe heat wave late in July, a normal occurrence, the range moisture gave out entirely, the soil became parched and dry, and the exhausted grass plants gradually gave up the struggle and finally ceased to throw up any more shoots. The grasshoppers, deprived of their succulent feed, and at this time being more mature, devouring every vestige of dry grass on the range, finally descended upon the plants within the fenced area. The fenced bunch grass winter ranges were likewise entered at this season of the year and much damage resulted. The main injury was caused by the grasses being gnawed at a point about an inch from the ground, allowing the stems to fall over in any direction and this resulted in a shortage of fall feed for the cattle. The seeds, however, were mature and the longer growing season enabled the plants to extend their root systems. Consequently, in so far as the ultimate condition of the range was concerned, no permanent damage was caused. In the autumn, during the period of grasshopper oviposition, it was further observed that *Camnula pellucida* (Scudder) did not select the five acre fenced area or the winter ranges as egg-laying grounds owing to the fairly dense growth of grass present, but chose in preference the barren ground on the range, where closely grazed tufts of grass occurred. Had this five acre plot been an area of fifty miles square, a re-established range, replete with abundant feed, would have been the result. Furthermore, this territory, except for normal outcroppings of gravel, poor soil or alkali, which support poor stands of grass under ordinary conditions would not have been chosen as egg-laying grounds. A greatly restricted oviposition area would have resulted, a factor of first importance in promoting the effectiveness of parasites, predators and other natural controlling factors.

An extensive series of observations have also indicated that a depleted range, provided it has not degenerated into the third stage of development as mentioned on page 10 may be restored to a satisfactory grazing area in from four to five years.

These remarks, according to the evidence in hand, relate more particularly to the Riske Creek range area in the Chilcotin district described in this bulletin, an area which, on the whole, is in a poorer state of preservation than the Kamloops-Nicola area.

The Kamloops-Nicola area presents a somewhat different condition. This range at one time supported many more cattle than it does to-day, and the stock-owners, realizing the necessity of preserving the native grasses, did fence considerable areas. The destructive roadside grasshopper was unquestionably present in this area in considerable numbers even before its utilization as a cattle range. Unfortunately the district appears to be particularly favourable to the development of this grasshopper, as immense areas suitable for egg-laying occur on the alkaline flats surrounding the larger lakes, and upon the extensive dry sand hills around Minnie lake which are normally clothed with a carpet of short growing grasses.

Some Indian lands and certain commonages are in many places badly overgrazed (fig. 12), and these also serve as breeding grounds for grasshoppers. The extent and number of suitable breeding grounds in the Nicola valley present a difficulty which was not present on the Riske Creek range. These egg-laying areas in the Nicola valley from which grasshoppers, in years of prevalence, sweep out in all directions, are now fairly well known. They should receive attention through efforts tending towards a re-establishment of suitable grasses.

In general, the main breeding areas of the more injurious species of grasshoppers, particularly *Camnula pellucida* (Scudder), are found in alkaline or gravelly portions of the range in areas partially denuded of their vegetation by overgrazing or in packed soil around ponds, caused by cattle and horses loitering

around watering places, or in any locations where the soil is either exposed to the full heat of the sun, or clothed with a short low-growing mat of vegetation. The proper care of water holes, a rotation system of grazing, the judicious use of salting-troughs, or any arrangement whereby portions of the range are kept free from stock during the growing period of the range grasses, will have a beneficial and lasting effect on the range condition. If re-seeding is practical over limited areas, this course may be pursued with good effect.

The various methods of control suggested for dry farming areas, for irrigated meadows, or for orchards and gardens, are not applicable to open range conditions, where the area is too immense to warrant their consideration except to a limited extent of which mention is made on page 17, or where a thoroughly organized campaign is arranged.

Control on Dry Farms

In many sections of British Columbia, verging on the open range, farms devoted to the raising of cereal crops may be found. These farms are commonly referred to as "dry" farms. The crops are often severely damaged by grasshoppers which migrate from the adjacent range. The control of grasshoppers under these conditions is naturally a very difficult matter as it is so closely related to the condition of the range adjoining. However, some relief may be expected by using arsenic in the form of a bait. This bait may be broadcasted on the surface of the soil among the growing crops. It is probable that more frequent applications will have to be made than in the case of an area entirely devoted to the raising of grain, and some attention may be necessary to the open range in the immediate neighbourhood of the crops.

The most satisfactory bait under these conditions is one containing the following ingredients:—

Dry powdered cattle manure	15 gals.
or	
Bran and sawdust, half and half by weight	25 lbs.
and	
Paris green or white arsenic	1 lb.
Salt water to thoroughly moisten.	

In preparing this bait the following procedure should be followed. The cattle manure, which in many localities is readily obtainable from the wintering sheds, should be allowed to dry. It is then pulverized as finely as possible. This is best accomplished with a rake or hoe. If manure is not obtainable, bran and sawdust should be purchased. These substances are then spread out evenly in a wagon-box, on a sheet of canvas or on the barn floor. Half the quantity of arsenic is then dusted over the dry material which is then mixed up thoroughly and respread. The remaining amount of arsenic is then added and well worked in. Paris green is used preferably, mainly on account of its colour which enables the operator to see if the mixture has been well made, which theoretically requires that every particle of dry bran or manure has a particle of arsenic adhering to it. Then the water is added. A barrel (40 gallons) is filled with water to which is added 10 to 15 pounds of common salt. This is stirred thoroughly to dissolve the salt and then added gradually to the dry ingredients, about two to three gallons of water being required to thoroughly moisten the 25 pounds of bran or manure. The completed mixture should not be "sloppy," but should fall readily through the fingers, rendering broadcasting by hand an easy matter. All animals and stock, of course, should not have access to the bait at the mixing plant and it should be remembered that the arsenic does not lose its strength by being allowed to stand. These piles of prepared bait may remain poisonous to cattle for a considerable length of time.

This method, as described, will be found practical, and applicable on small acreages. If larger mixing operations are considered desirable, a revolving tank consisting of tin or galvanized iron may be constructed. Stirring rods attached to the central pinion will greatly assist in breaking up the material, thus ensuring a better mixture. Home-made contrivances driven by motor or turned by hand may be constructed by farmers.

Often co-operatively controlled machines at central mixing plants may be arranged by a number of individuals. The bait as mixed under any system is usually placed in sacks or boxes to be hauled to the field as required. As a substitute for the white arsenic or Paris green constituent in the poison bait, Mr. C. L. Corkins, State Entomologist for Wyoming, U.S.A., recommends the use of sodium arsenite in the following combination for the control of adult grasshoppers:—

Bran or bran and sawdust, half and half by weight	100 lbs.
Sodium arsenite (commercial)	1 qt.
Salt	5 lbs.
Molasses	2 gals.
Amyl acetate (Tech. No. 1)	3 oz.
Water	10 gals.

The amount of sodium arsenite in the above formula may be reduced to one pint if used against nymphal grasshoppers. In preparation the sodium arsenite is mixed with the required amount of water and the liquid is then sprinkled over the bran which is vigorously stirred to ensure every particle of the bran being poisoned.

In applying the poisoned bait mixture, any suitable contrivance may be arranged to facilitate operations. It may be effectually done by hand, the bait falling lightly and evenly over the surface of the soil. An application of 25 pounds of the moistened bait to the acre is considered sufficient at one time. The grasshoppers will feed readily on this bait at any period in their lives, except during the first twenty-four hours, but the most suitable time of application, if it can be arranged, is when the grasshoppers are from a week to two weeks old. The period in the day when best results may be expected under "dry belt" conditions, is between 9 a.m. and 2 p.m. and applications should only be made when the shade temperature is over 60 degrees Fahr. The poisoned bait should never be applied on dull days; bright sunny days should be selected. It is impossible to state with any degree of satisfaction the number of applications necessary in the season; farmers must, in this particular, be guided by their own decisions.

This means of control by the use of a poison bait while particularly applicable to dry farms and ranch meadows may also be used on the open range, on commonages or on private holdings in a very much larger manner if facilities obtain. Under such circumstances it is necessary to stress the importance of dealing with those areas which are commonly regarded as centres for a grasshopper outbreak. Such areas should receive more attention in years when grasshoppers are not numerous than in years of outbreak.

Hopperdozers, chain or brush harrows all have a certain use under particular circumstances. For instance, a chain harrow made from sections of torpedo netting would, if drawn over flat pasture land devoid of large stones, prove useful in destroying recently emerged nymphs. None of these artificial control measures, however, are as successful as the arsenical bait when the latter is properly used.

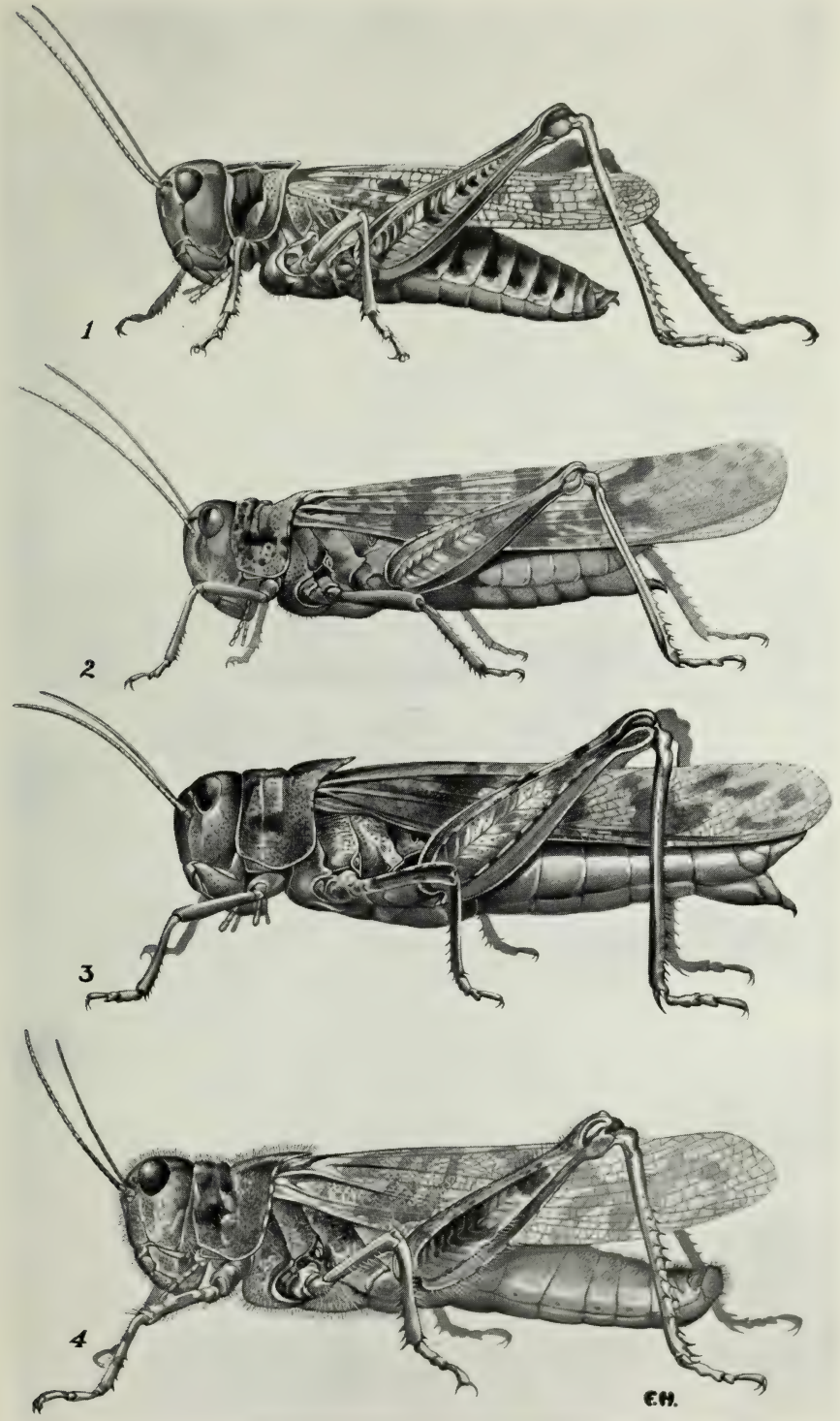
Control in Irrigated Meadows

In many sections advantage is taken of the availability of water for irrigation purposes. Crops of hay, alfalfa and grain are produced under these circumstances in meadows usually adjoining the ranch buildings.

Grasshoppers migrating off the range are liable to cause material damage to these crops. The same control measures recommended for use on the "dry" farms, may be employed using poison baits. In addition, however, the migrating swarms of grasshopper nymphs may be checked by taking advantage of irrigation courses by running water in open ditches. The nymphs which are unable to cross water are forced onwards by some propelling influence and surprising numbers are either drowned or float down stream. Here in angles of the ditches or clustering near obstructions the swarms accumulate. Where this occurs it is advisable to burn some straw or dry hay over them. Much may be accomplished at times by ploughing a ditch around the meadows and deepening it by hand. This procedure has proved effective on occasions against migrating swarms of nymphs. Obviously neither the irrigation ditch nor the open furrow is of any avail against migrating swarms of adult grasshoppers which fly in, at will, from the adjacent range. Under these circumstances poison bait applications are all that remain as effective procedures in control.

PLATE I

Fig. 1—Female of *Platybothrus brunneus* (Thomas) × 3.
Fig. 2—Female of *Trimerotropis monticola* Saussure × 3.
Fig. 3—Female of *Xanthippus neglectus* (Thomas) × about 3.
Fig. 4—Male of *Aerochoreutes carlinianus carlinianus* (Thomas) × 2½.


1
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E.H.

PLATE II

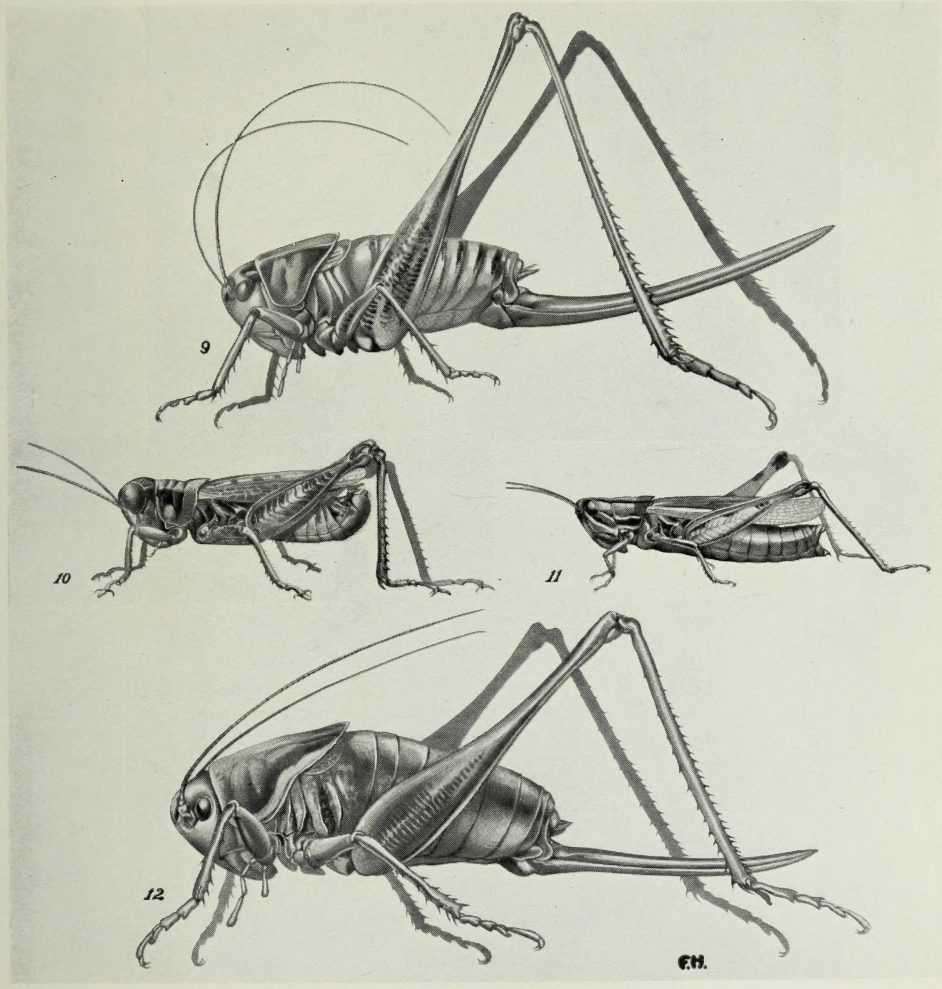
Fig. 5—Male of *Melanoplus bruneri* Scudder × about 3.
Fig. 6—Female of *Metator nevadensis* (Bruner) × 2½.
Fig. 7—Male of *Bradynotes chilcotinae* Hebard × 3½.
Fig. 8—Female of *Sphragemon aequale* (Say) × about 2¾.


5
6
7
8
F.H.

PLATE III

Fig. 9—Female of *Steiroxys trilineata* (Thomas) × about 2.
Fig. 10—Male of *Melanoplus infantilis* Scudder × about 3.
Fig. 11—Female of *Amphitornus nanus* Rehn and Hebard × $2\frac{1}{2}$.
Fig. 12—Female of *Anibrus longipes* Caudell × about $1\frac{1}{2}$.

PLATE III.



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